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Knowledge Elicitation: Phase I Final Report
Volume I

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This research note presents a framework for knowledge elicitation and representation based on theories of how experts themselves represent knowledge. Much previous work on knowledge elicitation has been guided by requirements of the systems for which the knowledge is to be encoded.

Two methodologies are presented: an interpretive method, based on the premise that experts organize knowledge in a "top down" fashion; and a generative method, based on the premise that they organize knowledge in a "bottom up" way.

The interpretive representation of expert knowledge integrates scripts, object frames, and mental models. The generative representation integrates production rules, semantic nets, and mental models. Knowledge elicitation techniques for each method are selected and tailored according to knowledge requirements of these representations.

Both methods were tested between subjects on ten situation development specialists and ten order of battle specialists in the Army Intelligence domain. Knowledge models (OVER)

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were constructed and evaluated for each of the methods, and the intelligence specialties. Results show that experts use a variety of knowledge structures in processing information and reasoning, and that both representations are necessary to capture expert knowledge adequately.

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EXECUTIVE SUMMARY

Research Requirement:

Much of the previous work on knowledge elicitation has been guided by requirements of the systems for which the elicited knowledge is to be encoded. The present paper reports a framework for knowledge elicitation and representation based on theories of how experts themselves represent knowledge.

Procedure:

Two methodologies are presented: an interpretative method, based on the premise that experts organize knowledge in a "top-down" fashion, and a generative method, based on the premise that experts organize knowledge in a "bottom-up" fashion. The interpretative representation of expert knowledge integrates scripts, object frames and mental models. The generative representation integrates production rules, semantic nets and mental models. Knowledge elicitation techniques for each method are selected and tailored according to knowledge requirements of these representations. Both the interpretative and generative methods were applied in the Army intelligence domain, between subjects on ten situation development specialists and ten order of battle specialists. Knowledge models were constructed and evaluated for each of these two methods and intelligence specialities.

Findings:

Experts use a variety of structures in representing knowledge and reasoning, that both interpretative and generative knowledge structures are necessary to capture adequately expert knowledge. In addition, the interpretative method seemed best at eliciting high-level goal and planning knowledge, while the generative method seemed best at eliciting situation specific rules and content knowledge. Situation development specialists tended to have more high-level and integrative knowledge while order of battle specialists tended to have more content knowledge.

Utilization of Findings:

The findings were used to evaluate the strengths and weaknesses of the two methods plus suggest ways for developing an improved integrated method. In addition, the findings suggest ways in which knowledge requirements and problem solving processes may differ across functional areas such as situation development and order of battle analysis.

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1.0 INTRODUCTION

1.1 Objectives

In the past decade and a half, increasing interest within both cognitive psychology and artificial intelligence has been focused on methods for eliciting and representing expert knowledge (e.g., Newell and Simon, 1972; Schank and Abelson, 1977; Hayes-Roth et al., 1983). As a practical by-product, computer-based aids (expert systems) have been designed to advise decision makers in a variety of fields, such as medicine and geological exploration; moreover, there is growing interest in other applications, such as matching personnel to jobs, the design of training programs, and the utilization of expertise to develop new standard operating procedures or doctrine. Despite its importance, however, knowledge elicitation continues to be an ill-understood and eclectic art, which demands enormous amounts of time and unusual forms of skill from both the elicitor and the expert. The elicitation process, and its attendant difficulties, raise fundamental issues about the data structures and reasoning strategies associated with diverse types of expertise, and about the manner in which such knowledge is tapped by different elicitation methods. These issues have not yet been dealt with in a satisfactory way, either in the artificial intelligence community or by cognitive psychologists.

The primary purpose of the work reported here is to amplify the synergy between theory and practice in the knowledge engineering field: in particular, to exploit theoretical models, findings, and methods in cognitive science, in order to develop and test an improved methodology for eliciting and representing knowledge.

The present report summarizes the results of the first year (Phase I) of a two-phase project sponsored by the U.S. Army Research Institute (ARI). The principle products of the completed research will include:

- a set of documented, improved knowledge elicitation methods;
- a documented, effective framework for representing the knowledge that is elicited;
- a preliminary (but expandable) set of guidelines for the use of different representation structures and elicitation techniques as a function of the domain, the task, the background of the expert, etc.; and
- the design of a computerized knowledge elicitation tool to assist in planning, conduct, and post-analysis of knowledge elicitation sessions. The aid will implement the elicitation methods, knowledge structures, and guidelines previously developed.

This report addresses our results to date under all but the last of these headings.

In conjunction with our sponsor, we have selected a specific area of knowledge as a concrete focus and testbed. The domain of primary interest is tactical military intelligence and within that, the subdomain of intelligence analysis. We have focused on two specific tasks at the Corps and Division level: maintenance of an enemy order of battle (i.e., the locations, composition, and organizational arrangement of enemy forces) and situation development (in particular, assessing enemy capabilities and likely courses of action). Finally, specific scenarios and problems have been developed within those tasks. Despite this detail, the elicitation methodology under development is quite general across scenarios, problems, and tasks in the intelligence domain. It is also intended to be applicable to domains that share key characteristics with intelligence analysis: in particular, reasoning with incomplete, unreliable, and inconsistent information.

Hoped for improvements in the elicitation process take a variety of forms: viz.,

- reduction in the time required for elicitation,
- increase in the consistency, accuracy, and generality of the knowledge elicited, and
- expansion in the types of expertise or degrees of expertise that are subject to elicitation.

While the primary goal of the project is to develop a general-purpose, theory-based elicitation methodology, it will produce secondary products that are of immediate use to the Army: (1) a partial knowledge base for tactical military intelligence analysis, and (2) a computerized elicitation tool that incorporates and utilizes built-in knowledge of the tactical military intelligence domain.

1.2 Basic Approach and Overview of the Report

The starting point for the present research is a conception of knowledge elicitation as a *constructive* process: i.e., that knowledge elicitation is, at the most general level, a joint problem-solving enterprise by the expert and the knowledge engineer. This conception implies: (a) that pre-existing knowledge is not simply transferred from the expert to the knowledge engineer and from the knowledge engineer into the computer, but is "constructed" (to varying degrees) during and after the elicitation dialogue. In other words, the elicitor's queries often do not trigger a canned response; in many instances they present a "problem" to be solved, through reasoning as well as retrieval, by the expert; similarly, the expert's answers often present a "problem" (of interpretation, follow-up, and formalization) to be solved by the elicitor; (b) that the quantity and quality of the knowledge that is elicited thus depend on the coordinated cognitive processes of both the expert and the elicitor. Section 2.0 outlines the basic support for this concept in the cognitive science literature.

At a more specific level, however, the existing cognitive science literature provides little guidance. A variety of competing structures for representing knowledge (e.g., scripts, frames, rules, semantic networks, and mental models) have been proposed, but there is little systematic understanding of their comparative strengths and weaknesses for describing different types of expert performance, or the way they might be related to one another in an integrated knowledge representation. Similarly, a variety of procedures for tapping expert knowledge have been utilized in practice and in experimental research (e.g., think-aloud problem solving, recall, sorting and similarity judgments, cloze (filling-in-the-gaps) experiments, etc.) but there has been little effort to study the capabilities and limitations of the procedures themselves, or to incorporate them into a systematic, integrated, practical method of knowledge elicitation.

The initial task of Phase I involved development of appropriate theory. Existing research on knowledge elicitation and representation was examined (including theories, models, and research findings, e.g., Leddo, Cardie and Abelson, 1987); a set of candidate elicitation techniques and representation methods were developed; and hypotheses were generated regarding their appropriateness for different types of problems and experts. A specific objective was to develop two contrasting methodologies for comparison: one appropriate for data-driven, bottom-up, or *generative*, modes of expert reasoning, and the other appropriate for expectancy-driven, top-down, or *interpretative*, modes of reasoning. Each methodology was to include multiple elicitation and representation techniques.

The principle results of this task are described in Sections 3.0 through 5.0. In sum, they include:

- two integrated knowledge representation structures: an *interpretative* structure that systematically combines scripts, frames, and mental models in complementary roles, and a *generative* structure that in a similar way combines rules, semantic relations, and mental models (Section 3.0);

- two integrated sets of elicitation techniques: an *interpretative* approach that combines a top-down, template-based interview with think-aloud problem-solving to instantiate principles elicited in the interview, and a *generative* approach that combines highly data-driven problem-solving with a bottom-up interview to extract general principles implicit in problem-solving performance. A general framework has been developed that characterizes these (and other) elicitation techniques in terms of the cognitive processes required of the elicitor and the expert (Section 4.0);

- a set of guidelines for the use of generative versus interpretative approaches, as a function of the expert (e.g., his cognitive style and organizational level) and the problem (e.g., degree of uncertainty) (Section 5.0).

The second task in Phase I involved a demonstration of the feasibility of the candidate elicitation and representation methodologies in the selected Army operational testbed, and an informal, qualitative comparison of the generative and interpretative approaches across two Army tactical intelligence tasks: order of battle and situation development. Testing occurred in two phases: (1) a pilot phase (involving retired intelligence officers provided by Burdeshaw Associates, Limited, and intelligence specialists at Fort Huachuca and Fort Leavenworth), and (2) a primary phase (involving intelligence specialists from the 82nd Airborne Division at Fort Bragg, the 4th Infantry Division at Fort Carson, and instructors at the Army Intelligence Center and School at Fort Huachuca). The methods and rationale of these two phases are described in Section 6.0. Appendices B and C contain materials used in the primary phase of the demonstration.

A by-product of these field demonstrations was that actual knowledge relating to the conduct of Army intelligence was collected and represented. Since the primary purpose of the elicitation was to develop a better understanding of the techniques, virtually any knowledge relevant to performance in the selected testbed was a candidate for elicitation. Nevertheless, wherever it was consistent with the primary research objective, attention was focused on knowledge that (a) appeared more critical for potential technology applications (expert systems, personnel screening, and training in that order), and that (b) is not adequately elicited or represented by existing methods. The latter category includes knowledge that goes beyond written doctrine and standard training, knowledge that is not naturally represented by rules, knowledge that is not easily articulated, knowledge involved in exceptional (expert-level) performance, knowledge of a rapidly evolving domain, etc. In general, our interest extended both to substantive beliefs about the domain (e.g., enemy tactics) and to methods of reasoning with those beliefs. Appendix D contains four formally represented databases of elicited knowledge, derived from the interpretative and generative approaches, and pertaining to order of battle and situation development respectively. (We should note, however, that within the constraints of time and resources imposed by this project, it is impossible to guarantee the completeness or accuracy of all the elicited data.)

The final task in Phase I involved the development of representational models for the elicited knowledge, and an evaluation of the performance of the two methodologies as a function of characteristics that differentiate the two Army intelligence tasks. Appendix D, as noted, presents the representational models. Section 7.0 includes annotated protocols of elicitation sessions, followed by step-by-step descriptions of the process of building a knowledge model from the transcript data. Section 8.0 presents conclusions of the first year of research and outlines plans for Phase II.

2.0 COGNITIVE SCIENCE BACKGROUND: A CONSTRUCTIVE VIEW OF KNOWLEDGE ELICITATION

2.1 The Myth of "Mining for Nuggets" of Knowledge

The central question in the field of artificial intelligence, whether computers can be made to *think*, has always focused on tasks (such as chess) where a formal algorithmic solution (i.e., an automatic "mindless" approach) was unavailable or impractical. Early work in artificial intelligence focused on general-purpose technologies for *reasoning*. For example, one very general approach to problems is means-ends analysis (Newell and Simon, 1972): compare the goal (e.g., checkmate) with the existing state of affairs and search memory for operations (e.g., chess moves) which will reduce the difference (this may recursively involve searching for operations to reduce differences between a state-of-affairs and the condition for applying the operator). Methods such as this were implemented in simple, well-defined contexts besides chess, such as blocks-world (Winograd, 1972) and "cryptarithmetic" (Newell and Simon, 1972). The focus of research shifted to *expert systems* with the realization that such general-purpose techniques were not sufficient for the solution of more realistic, complex problems.

In many such problems (including chess), the number of possible solutions (i.e., combinations of operations that *might* link the goal and the existing state of affairs) is very large. In those cases, real-time outputs depend on methods for reducing search effort--e.g., the selection of representation schemes, or ways of slicing up and describing the problem, which are highly tailored to a specific domain and the ability to evaluate and eliminate large classes of potential solutions without exhaustive search (cf., Amarel, 1980). A chess-playing expert system, for example, might consider whole sequences of moves or strategies, rather than individual moves, and evaluate the board positions to which they lead in terms of relatively subjective attributes like "domination of center positions." More generally, expert systems make primary use of domain-specific judgmental *knowledge* (i.e., heuristics) rather than *reasoning* methods or brute-force search techniques.

As a result, in typical expert systems applications, the highest available standard of reasoning in the relevant domain is expert practice itself; and much of the effort in expert system development consists in the extraction of specialized knowledge from human experts and its translation into machine-usable form. Typically, a computer scientist (or knowledge engineer) is required to serve as mediator between the domain expert and the computer in the process of "authoring" a knowledge base. The knowledge engineer must identify and define the problem, and develop an initial understanding of the problem domain. Then he or she must tentatively choose an appropriate knowledge representation, reasoning mechanism, and user-system interface; elicit the knowledge from experts, revising if necessary his or her initial design choices; and validate the system. Progress in automating the knowledge engineer's role--i.e., machine learning from direct exposure either to the expert or to the domain--has been limited.

Why is knowledge elicitation hard? We would argue that knowledge elicitation is seldom (if ever) the literal "transfer" of information from expert to system:

- No matter how much time is spent with the expert, the data will always be incomplete and compatible with a variety of different hypotheses regarding his knowledge and reasoning methods. The knowledge engineer must fill in gaps, identify possible lapses or errors, and extrapolate from the observed set of problems to others that may occur in the domain. (This is true even if the knowledge engineer *is* the expert.)

- Often, expertise has been developed over a unique and lengthy series of problem-solving experiences in a domain. Such knowledge does not permit easy verbal articulation, even by the expert.

- Some of the information, on the other hand, may be in textbooks or other articulable form. Indeed, experts often have command over a multiplicity of representations, knowledge sources, and problem-solving strategies. These must be sorted out, their proper roles identified, and apparent inconsistencies resolved.

- The knowledge engineer must work with elicitation methods which may themselves distort or influence the character of the expert's inputs in unknown ways.

- The knowledge engineer must translate the expert's knowledge into computer implementation formats that are limited in their ability to capture the flexibility and variety of human concepts and reasoning methods.

- Expert knowledge is typically "heuristic" or judgmental. Methods for capturing expert judgment may yield results that apparently diverge from normatively justified principles for reasoning (e.g., the work of Kahneman and Tversky). What is at fault: the experts, the normative principles, or the elicitation methods?

- Multiple experts in the same domain may disagree in their methods, in their conclusions, or in both. What criteria can be applied for calibrating degrees of expertness? When should competing views be reconciled, and when should the possibility of alternative approaches, and even multiple possible conclusions, be allowed for?

Clearly, the metaphor of knowledge elicitation as "mining" for "nuggets" of knowledge (e.g., Hayes-Roth et al., 1983) is misleading. There may be no static "nuggets" waiting to be found. In our view, elicitation is a process of *definition* and *redefinition*, in which the knowledge engineer creatively models the observed data while striking a

balance among competing representational constraints. In such a process, both the expert's and the knowledge engineer's picture of the knowledge may shift as multiple viewpoints are explored.

2.2 What is Expertise?

Is there something qualitatively distinctive about the representations and/or methods of reasoning of experts as compared to non-experts? Does the *character* of knowledge, as well as its *quantity*, change as a novice becomes an expert? It is commonplace that expertise accrues over extended experience in a domain. It is not so obvious, however, how it accrues (Is experience necessary but not sufficient? What kind or kinds of experience? Is a certain type of preparedness also required?). Nor is it clear what it is that accrues or, in a practical vein, how experts may be identified for such purposes as job assignment, expert system knowledge elicitation, or codification of doctrine. Finally, it is not clear that expertise means the same thing or develops in the same way in different fields.

In rare instances, it may be possible to collect sufficient quantities of representative data under sufficiently controlled circumstances to distinguish experts from non-experts, by significantly superior performance measured against a relatively objective standard (e.g., number of surviving patients with a specific ailment). More often, however, such data are unavailable either in practice or in principle (for example, expertise in military tactical intelligence might only be fully *tapped* under warfare conditions, but an objective ground-truth measure would only be available in peace-time exercises). In these cases, the only present recourse is to utilize imperfect indicators: either presumptive causes of expertise (type of training, years of experience) or presumptive effects (organizational rank, the consensus of colleagues). A more theoretically well-founded criterion of expertise, in terms of internal properties of reasoning or knowledge, which may appear in virtually any sample of performance, might well have important practical implications.

A body of research suggests that the development of expertise follows two distinct, and apparently contrary, paths: on the one hand, toward an increasing repertoire of direct, prepackaged responses to the environment; and on the other hand, toward a growing ability to reason abstractly and flexibly about the problem domain. On the first path, experts are adaptively controlled by the immediate environment; they quickly and intuitively "see" the right answers without the need for much, if any, thought. On the second path, experts are freed from the immediate environment to plan further ahead, and to anticipate less directly related consequences. The first path is associated with bottom-up, *generative* problem-solving, in which data directly trigger cognitive processes that lead to increasingly higher-level conclusions. The second path is associated with top-down, *interpretative* problem-solving, which utilizes models and beliefs at a high level and works downward to predictions about the data. A hypothesis which we shall explore is that generative knowledge is associated with *procedural* representations, which specify

cognitive operations in an inflexible, but highly efficient way; and that interpretative knowledge is associated with *declarative* representations, which lend themselves flexibly, but less efficiently to a variety of uses. It is illuminating to consider how each dimension of expertise may be utilized to grapple with novelty. In effect, there are three levels at which adaptation might take place:

- The selection and shaping of (generative) *behavior* by direct experience of success and failure in the problem *environment*;

- The selection and shaping of *plans* or *hypotheses* by vicarious experience of success and failure in an interpretative *model* of the problem environment;

- The exploratory generation of new interpretative *models* and their evaluation in terms of the accuracy of the predictions to which they lead.

These three forms of learning represent increasing levels of adaptiveness to potential *changes* in the environment, and decreasing levels of efficiency in dealing with routine or familiar aspects of the environment. Their relative prominence in any particular application may well depend on the nature of the problem domain, the familiarity of the problem, and perhaps on the cognitive style of the expert.

In the remainder of Section 2.0, we briefly consider each type of expertise and then turn to some implications for the elicitation process.

2.2.1 Generative expertise. Expertise is often equated with "know-how," and one difference between experts and novices may lie in the distinction between *knowing how* and *knowing that*. Extensive practice (e.g., riding a bicycle, speaking a foreign language) may lead to a direct, "intuitive" skill on the part of the expert, which he himself is unable to articulate or explain. While the novice may be able to express many facts about the domain (i.e., know that...,) he may lack this essential know-how.

Two recent theories have attempted to account for expertise along these lines: the "compilation" of knowing how from knowing that, and the ability to perceive the environment in increasingly large "chunks."

Any symbol system, whether human or computer, can be regarded as consisting of (a) a set of data structures and (b) the processes which interpret and manipulate them in order to draw conclusions (cf., Anderson, 1978; Newell, 1981). Anderson (1982) has proposed a detailed cognitive architecture in which: consciousness (knowing that) is identified with the data in working memory; procedural knowledge (knowing how) is represented in the form of if-then production rules; and the development of cognitive skill involves a shift from (a) explicit declarative knowledge to (b) implicit procedural knowledge. The first phase of skill development is *declarative*: domain- or problem-specific facts are retrieved from long-term memory, explicitly represented in working memory, and interpreted by general-purpose problem-solving procedures. The declarative information in working memory triggers the application of

"if-then" production rules, or procedures, which in turn activate new declarative information triggering new rules, and so on. Through successful repetition, a process akin to the compilation of a computer program occurs: specialized procedures are created which take over the functions of the declarative knowledge. One subprocess involved in compilation is composition, which collapses rules that tend to be triggered in sequence into a single procedure. Another subprocess, proceduralization, replaces generally stated rule conditions (that require specialized declarative knowledge for their use) with specific rule conditions.

Figures 2-1 through 2-3 illustrate very roughly the successive stages of expertise according to Anderson's theory. Notice that for the novice (Figure 2-1), virtually all the knowledge pertaining to attack planning must be retrieved from long-term memory and explicitly represented in working memory. By contrast, in the final stage of development (Figure 2-3) this same domain knowledge is directly embodied in processes. (According to Anderson, procedural knowledge may continue to improve through processes of discrimination and generalization.) Anderson links his concept of procedural knowledge with the notion of "automaticity" in Schneider and Shiffrin (1977). Automatic/procedural performance is faster (since it requires fewer steps) and less likely to interfere with the parallel performance of other tasks (since it demands less space in working memory). By the same token, it is less accessible to conscious awareness.

Experimental data suggest that expert knowledge may in fact undergo a developmental sequence of this kind. Most of these data come from think-aloud problem solving protocols. For example, in a study comparing expert and novice performance on physics problems, Larkin et al. (1980) found that novices used general problem-solving methods, e.g., they worked backward from the unknown through various subgoals (e.g., solve an equation containing the unknown) to the given quantities. Novices explicitly mentioned the equations used at each stage. Experts, by contrast, were faster, worked forward from the given to the desired quantities, and usually verbalized only numerical results rather than the equations themselves. These findings suggest that novices have domain-specific declarative knowledge (viz., *knowledge that* certain equations are useful for various purposes) and general-purpose procedural knowledge for applying it (e.g., *knowing how* to do means-ends analysis); but that experts store entire domain-specific solution methods as unitary procedures. In sum, experts substitute relatively shallow chains of automatic stimulus-response relationships for the more elaborate and self-conscious problem solving of sophisticated novices.

Declarative Knowledge in Working Memory	(Implicit) Procedural Knowledge
• Goal = plan an attack with 1st and 2nd Brigades • 3-to-1 ratio necessary for successful attack	If A is a goal and doctrine says B is required for A, adopt B as subgoal.
• Subgoal = Achieve 3-to-1 force ratio for 1st and 2nd Brigades • Current ratio for 1st Brigade = 3-to-1, for 2nd Brigade = 2-to-1, (from status reports)	If A is goal and B is current situation, find difference C between A and B and make reducing C a subgoal.
• Subgoal = reducing difference between 3-to-1 and 2-to-1 ratios for 2nd Brigade	
• Reinforcement is a method for increasing force ratio (from doctrine) • Reinforcement consists of moving troops from one unit to another unit that is to be reinforced (semantic knowledge)	If a goal involves n objects and some of the objects are known, make finding the unknown objects a subgoal.
Subgoal = find a unit to serve as a source of reinforcements for 2nd Brigade. Infantry units should be reinforced with tanks. Tank units should be reinforced with infantry. (from doctrine)	If A is a goal and doctrine says B is required to achieve A if C is true, and D is required to achieve A if E is true, then find out if C or E is true.
2nd Brigade is infantry (from long-term memory)	If A is a goal and doctrine says B is required for A, then make B a subgoal.
Subgoal: *find a tank unit as source of reinforcements* 1-49 Armored Battalion is a tank unit (from long-term memory)	If A is a goal and a way to achieve A has been found, then consider the goal success.
(All goals marked as successful) ACTION = Reinforce 2nd Brigade unit with 1-49 Armored Battalion	

Figure 2-1. A Novice's Declarative Knowledge Representation.

(Explicit) Declarative Knowledge	(Implicit) Procedural Knowledge
Goal = plan an attack with 1st and 2nd Brigades	
Current ratio of 2nd Brigade = 2-to-1 (from reports)	
2nd Brigade is an infantry unit	
1-49 Armored Battalion is a tank unit	
	If the goal is to attack with an infantry unit and the ratio of troops is less than 3-to-1, then reinforce with a tank unit.
Reinforce 2nd Brigade with 1-49 Armored Battalion	

Figure 2-2. After Composition.

(Explicit) Declarative Knowledge	(Implicit) Procedural Knowledge
Goal = plan an attack with 1st and 2nd Brigades	
Current ratio of 2nd Brigade = 2-to-1 (from reports)	
	If the goal is to attack with 2nd Brigade and the ratio of troops is less than 3-to-1, then reinforce with 1-49 Armored Battalion.
Reinforce 2nd Brigade with 1-49 Armored Battalion	

Figure 2-3. After Proceduralization.

Other research suggests that implicit procedural knowledge may evolve directly from experience in a domain, without an initial stage of explicit declarative representation. Berry and Broadbent (1984) found that practice in a complex, computer-implemented control task improved performance, but did not improve subjects' ability to answer questions about the task. Verbal instructions had the converse effect. Moreover, there was a negative correlation between subjects' ability on the task and their ability to answer explicit questions about it, when task solutions were not obvious or salient If task knowledge were originally represented in declarative form, a positive correlation would be expected--*assuming* that the original declarative knowledge could be reliably recalled and verbalized.

It may not be safe to assume, however, that declarative knowledge is always accurately describable. Declarative knowledge includes not only generalizations (such as, a 3-to-1 force ratio is necessary for a successful attack), but also internal representations of particular successful or unsuccessful problem-solving *episodes*. Such episodes may involve examples of problem-solving by others, or one's own trial-and-error experiences. There may be general-purpose procedures for utilizing such episodic memories for the selection of a response in new, similar problems (Anderson, Greeno, Kline, and Neves, 1981). Attempts to *describe* such episodes, however, may invoke different procedures, which depend more heavily on conventional or stereotypical notions of how the task should be solved, and therefore focus on different aspects of the remembered situation. There is considerable evidence regarding the unreliability of "autobiographical" *episodic memory* (e.g., Loftus, Fienberg, and Tanur, 1985; Bradburn, Rips, and Shevell, 1987).

A second theory of expertise, which also associates expert knowledge with increased automaticity, involves the notion of *chunking*. Introduced by Miller (1956), chunking is the ability to organize a number of items of information into a larger grouping, which is then treated as a single unit. DeGroot (1965) utilized this idea to explain the knowledge of chess masters. DeGroot found that masters far outperform novices in the short-term recall of chessboard patterns. This advantage disappeared, however, when the chessboard configurations to be recalled were constructed randomly, suggesting that chess masters are not simply better at memorizing the location of individual pieces. Rather, they are able to recognize and identify familiar structural relations in the legal chessboard patterns. DeGroot concluded that expertise in chess lies in direct, automatic linkages between these perceived structural relations and learned strategies or responses. Fast unconscious processing thus replaces the novice's conscious, slow reasoning.

Newell and Rosenbloom (1981) have proposed a general theory of skill (perceptual, motor, and cognitive) based on chunking. In a wide variety of task domains, including problem-solving, it has been found that the time required to perform a task is a power function of the number of trials of practice at tasks of that type. Newell and Rosenbloom explain the improvement due to practice in terms of a constant rate at which task elements are encoded into larger chunks. A power function (rather than the expected exponential function) can be derived on the hypothesis that

chunks formed later in practice are larger than those formed earlier; hence, they are more specialized, i.e., less likely to recur and be used in the solution of subsequent problems.

2.2.2 Declarative expertise. Compilation and chunking have their primary effect on the speed of performance, by collapsing large numbers of operations into single routines. Qualitative changes in performance (e.g., working forward to the solution rather than working backward from the goal) are incidental by-products. Improvements in the level of performance are also by-products, resulting from the ability to generate a larger number of possible solutions in a shorter period of time. Moreover, there is a self-limiting character to the improvements created by compilation and chunking: the increasingly specialized structures they produce have a correspondingly decreased range of useful applications.

Nevertheless, there is evidence that the superiority of experts goes beyond the rapidity with which operations are performed. Experts appear to have knowledge structures that are both more general and more flexible than those of novices. Evidence for the special character of expert representations comes from a variety of studies, utilizing similarity judgments, clustering in recall, and think-aloud problem solving.

Similarity judgment. In physics, Chi et al. (1981) found that experts and novices differ in the way they sort problems by similarity. Novices categorize problems by "surface structure," i.e., superficial features such as type of apparatus, while experts rely on basic principles of physics (e.g., conservation of energy) and *generic solution techniques* associated with such principles. Similar differences between experts and novices in algebra are reported by Shoenfeld and Herrmann (1982): algebra experts sort problems by solution method, while novices depend on words or objects mentioned in the problem statement. Weiser and Shertz (1983) replicated these findings for computer programming: experts sorted programming problems by reference to the types of algorithms that would be employed in solving them, while novices sorted by reference to the application area from which the problem was drawn.

Clustering in recall. Chase and Simon (1973) analyzed pauses in the recall of chessboard configurations, as well as visual glances in the perceptual reconstruction of chessboard configurations. The clusters identified in this way for chess masters suggested that the meaningful patterns within the chessboard were classified and understood at an abstract level, e.g., as "attack" configuration or "defense" configuration. McKeithen et al. (1981) obtained similar results in a study of clustering in the recall of computer programming concepts by expert and novice programmers. Adelson (1984) replicated the results in a study of the order in which scrambled lines of a computer program were recalled: novices clustered by syntactic similarity, while experts grouped lines that formed semantically meaningful program modules.

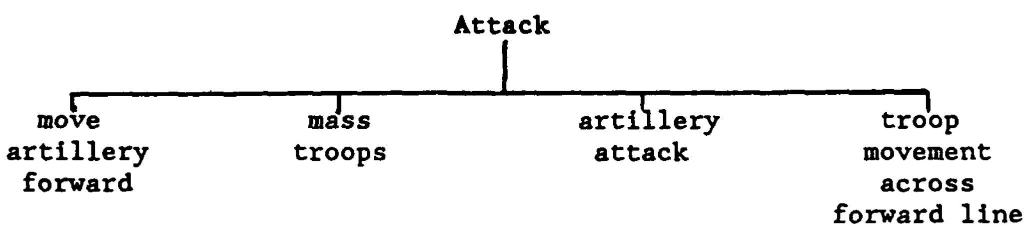
Think-aloud problem-solving. Evidence that abstract concepts are actually used in expert problem solving comes from think-aloud protocols. In physics (Larkin, 1981) and geometry (Greeno, 1983), the entities mentioned in expert as compared with novice protocols tend to be technical rather than familiar, and to be closely tied to fundamental laws. Larkin

et al. (1980) and Novack and Araya (1981) found that physics experts associate specific types of problems with idealized spatial representations of the objects and relations involved in those problem-types. In solving a problem, experts utilize qualitative rules to infer unknown properties within these representations from those that are known, rather than working explicitly with equations. Larkin (1981) identifies a number of aspects in which expert inferential processes are more general, and therefore more powerful than those of novices: e.g., (a) properties of objects, as perceived by experts, are local rather than defined in terms of expected effects on other objects, thus permitting use of knowledge about these objects across a wider range of contexts; (b) inference by experts involves atemporal constraints as opposed to single-direction temporal simulation, thus permitting the same parameter to serve as an input in one problem context and as an output in another; (c) the same solution can be arrived at in more than one way, utilizing different inputs.

These and other findings suggest that experts not only respond directly and intuitively to perceived structure, but actively utilize cognitive structures to organize their knowledge and to derive predictions and expectations. Improved capacity for *top-down* processing thus seems to characterize expertise as much or more than improved bottom-up processing.

An important additional feature of this top-down processing, particularly emphasized by Larkin, is the flexibility or redundancy that it incorporates. It is this feature that suggests an advantage of declarative over procedural representations for such knowledge. The key distinction between the two is that procedural representations specify the use to which the knowledge is to be put; thus, each potential use requires a separate representation. Declarative representations, by contrast, can be utilized (by general-purpose procedures) in a variety of ways.

For example, one type of declarative representation, the script (Schank and Abelson, 1977), represents a stereotypical sequence of events associated with some activity or goal. An extremely simplified example might be the following *attack* script:



This same script can be utilized either for understanding a situation or for planning one's own actions, while large numbers of different production rules would be required for each purpose. In situation understanding, if *any* one of the specified events is observed, the others can be inferred (with some degree of uncertainty): e.g., after a massing of enemy troops is observed, we may infer that artillery have been already moved forward, and we may expect an artillery attack and forward troop movements in the near future. Similarly, if an artillery

attack is observed, we expect troop massing to have already taken place, and troop movements to be imminent. By contrast, in a production rule representation, separate rules would be required for each possible input. In planning an attack, similarly, the same script may be utilized to identify and organize actions that we must take at *any* stage of the attack. Finally, note that the same knowledge structure could be used (in conjunction with linguistic procedures) to generate verbal descriptions of an attack or to answer questions.

It is clear that procedural and declarative representations reflect contrasting criteria of efficiency. Procedural representations maximize the speed of a specific, adaptive set of responses to a specific set of stimuli. Declarative representations, on the other hand, maximize the amount of information that is communicated in a given period of time. Any part of a declarative representation can lead (perhaps with some uncertainty) to a reconstruction of the whole (Bruner, 1956, p.46). Declarative structures, then, capture the redundancies in the problem solver's environment.

Eleanor Rosch (1983, 1978; Rosch et al., 1976) has provided empirical support for a view of this sort, with respect to categories in natural language. According to Rosch, objects are not simply arbitrary ways of slicing up the world into classes. In such taxonomies there is generally one level of abstraction that is more basic than the others, i.e., learned earlier, and used most often in acting upon, thinking about, or naming the object. For example, terms like *dog*, *cat*, and *lion*, are at the basic level of abstraction, by contrast with more abstract terms like *mammal* or *animal* and more concrete terms like *spaniel* or *collie*. Rosch proposes an explanation of this phenomenon in terms of the adaptiveness of categories to the correlational structure of cues in the environment. The basic level of abstraction is the most inclusive level in the taxonomy at which there are attributes common to most or all of the members of the category. At too high a level of abstraction (e.g., *mammal*), there is less similarity among members of the category, and as a result we are less able to predict what the object is like (or what actions we should take with regard to it) from the category name. At too low a level of abstraction (e.g., *collie*), there are too many properties and actions) in common with other categories (e.g., other types of dogs), and cognitive economy is unnecessarily sacrificed. Basic-level categories thus best achieve the two purposes of a categorization system: (1) to enable us to predict as many properties as possible from any other, and (2) to bring pragmatically useful order to the infinite differences among stimuli. Basic categories provide the most information with the least effort.

It seems plausible to suppose that the development of expertise is, in part at least, a continuation and intensification of the process involved in language learning. The categories employed by the expert, while more abstract and technical, give him a more powerful tool for exploiting regularities in his environment.

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3.0 KNOWLEDGE STRUCTURES AND ELICITATION STRATEGIES

Psychological studies of expert problem-solving behavior give evidence of an interactive use of both high-level, relatively abstract domain knowledge and goal-directed planning with lower-level, more concrete and detailed information and rules of action. It would follow that methods of elicitation geared to capture knowledge at those different levels of abstraction would be more effective in the acquisition of the problem-solving knowledge that real experts use, than standard elicitation approaches that do not recognize explicitly the use of diverse forms of knowledge.

In this section, interpretative and generative types of knowledge will be described at greater length, along with a description of various knowledge structures amenable to the representation of interpretative versus generative knowledge, and how these structures can be integrated. This will be followed by a general discussion of elicitation strategies and candidate strategies that promise to be effective in eliciting these two different kinds of knowledge. We will then consider the interaction of interpretative (top-down) and generative (bottom-up) knowledge in the course of problem solving, in conjunction with methods for elicitation of problem control knowledge and appropriate structures for the representation of the flow of control and attention across levels of abstraction in the process of solving domain problems. Finally, we discuss some other issues that are important to the ultimate success of elicitation concerning the purpose of the expert knowledge elicitation and the nature of "expertise."

3.1 Interpretative Versus Generative Knowledge

Interpretative knowledge involves the high-level goals, plans, and strategies needed for problem solving within a domain, to provide an overall direction for the more detailed problem solving required to achieve intermediate subgoals. Interpretative knowledge also refers to the complex, semantically rich units of knowledge about objects and processes, on which people base actions, assumptions, and expectations. For example, most Army officers have some interpretative knowledge about how to conduct rear area protection (RAP) operations, and if an ammunition supply unit receives a report of Level II enemy activity behind friendly lines, the commander can assume his unit is a potential target. He would expect the threat to consist of small teams of special forces, using small automatic weapons and explosives, without armored vehicle support. They would probably attack in darkness to achieve surprise, attempt to destroy as much as possible, and then withdraw within half an hour. Upon receiving the report of enemy activity, the commander would plan to increase perimeter guards, rehearse the unit quick response team, and notify the rear area operations center (RAOC). He would seek to secure his area, prevent or minimize enemy interference with his mission, and help the RAOC to find, fix and destroy the enemy threat. These expectations, plans and goals will serve to direct the more specific and concrete actions that the commander will take to perform rear area protection.

Problem-solving that involves the use of this sort of contextual or general knowledge has also been referred to as top-down processing because the high-level general knowledge largely determines the interpretation of (and thus the response to) low-level perceptual units.

Generative knowledge is more concrete, specific and perceptual. Objects and processes at this low level are components from which patterns are generated, and subsequently recognized and acted upon. Referring to the rear area protection example again, if a guard post alerted the base defense operations center (BDOC) of suspected movement, the commander would probably send a patrol to investigate. If the unit came under small arms fire, the commander would order all soldiers to their fighting positions and alert the RAOC. If the unit began receiving indirect or heavy weapons fire, he would request support from the RAOC, or send his quick response team to destroy the source of the firing. If the unit perimeter were penetrated, he might initiate emergency action procedures such as destruction of nuclear warheads, or call for artillery or air strikes on the overrun positions. Thus, generative knowledge is concerned with the piecing-together of specific and concrete information in order to make an inference or to determine a course of action, also referred to as bottom-up processing.

3.2 Structures for the Representation of Interpretative and Generative Knowledge

In this section, we will describe a variety of knowledge structures with which expert knowledge can be represented once it has been elicited. Although there are several candidate structures for interpretative knowledge and for generative knowledge, each individual structure has some shortcomings as well as strengths in its ability to represent expert knowledge at a given level of abstraction. Thus, our discussion will also consider strategies for the amalgamation of different top-down versus bottom-up structures, to produce integrated approaches to the representation of interpretative versus generative knowledge.

3.2.1 Interpretative knowledge structures.

The structures that will be considered for the purpose of capturing top-down problem-solving knowledge include scripts, frames, and high-level mental models.

Although it has sometimes been argued that each of these structures could individually accommodate the range of knowledge needed for intelligent problem solving, they are very well suited to address the questions of "How?" "What?" and "Why?" respectively. Scripts provide descriptions of sequences of actions to obtain goals, frames provide rich and detailed descriptions of objects, and interpretative mental models provide high-level descriptions of causal processes involving a particular set of objects and prompting particular actions.

Scripts. People appear to make use of *scripts* (Schank and Abelson, 1977) when planning actions for problem solving or forming expectations about future sequences of events. A script has been defined as a "causal chain" that describes appropriate sequences of events in a particular context. It is made up of slots and requirements about what can fill those slots. What is in one slot affects what can be in another.

Figure 3-1 gives an example of a script representation that provides a rather simplified description of the G2's procedure for requesting aircraft reconnaissance. The *script* slot contains a description of the general area of operations to which the process description pertains. The *track* slot identifies the specific task of interest. *Roles* should contain a listing of all actors who will play a part in the sequence of events that comprise the task. *Props* contain a list of all the objects that will play a part in the sequence of actions described in the script. *Entry conditions* describe the features of the problem or situation that are necessary for this particular script to be applied. *Results* describe the net outcome of the sequence of actions described in the script. This is generally a description of players or props that undergoes change in the course of actions in the script.

The information described in the aforementioned slots provides a preliminary introduction and summary of the more detailed sequence of actions that follows. The remainder of a script consists of a series of *scenes* (rather like the script of a play, but without much dialogue) that describes the required sequence of subtasks and procedures for performing them.

While script structures provide a very useful format for representation of familiar processes at various desired levels of detail, they are not readily changed (McArthur, Davis and Reynolds, 1987), nor do they provide the apparatus for handling totally novel situations. They are predetermined, stereotyped sequences of actions that define well-known situations, but do not explicitly account for causal processes. Thus, there are real limits to their flexibility. Scripts are therefore not a particularly suitable structure for representation of processes driven by a complex and rapidly changing environment.

Object Frames. Knowledge about an object can be organized into a semantically rich representation, referred to as a *frame* (Minsky, 1975) or object *schema* (Anderson, 1980). The knowledge within a frame can be hierarchical in structure, and the frames for different objects can, in turn, be represented in the form of a network. The object frame nodes are defined by a collection of attributes (slots) and values for those attributes (e.g., a range-admissible value, or a default value). Although different frames used in the same system must have the same slots or terminals, the particular set of attribute slots can vary according to the descriptive needs of the system. Examples of attribute markers are HAS-PART, HAS-COLOR, HAS-SIZE, HAS-GOAL and category-member keys, such as A-KIND-OF, SIMILAR TO, IS-A, PART-OF.

In addition to object frames, one can have action *frames specifying* the action (e.g., MOVE, GIVE, TAKE, etc.) and the set of objects involved, such as an ACTOR, an OBJECT, action SOURCE, DESTINATION, and relevant RESULTS and/or SUBPROCESSES.

SCRIPT: describes appropriate sequence of events in a particular context.

Script:	intelligence collection	Roles:	G2 G2's Commander Aircraft Commander
Track:	air reconnaissance request		
Props:	map current intelligence estimate request form communications link between players aircraft		

Entry Conditions:	Results:
G2 identifies serious potential threat	G2 has more info: makes better assessment
G2 needs high quality intelligence to refine threat assessment	Air surveill/recon. resources reduced in short run
G2 intelligence needs is urgent	
Commander can officially obtain aircraft reconnaissance	

- -

Scene 1: G2 identifies info need (entry)

(G2, current intell or own force and enemy forces) locate info, etc. needs in maps, space & time

Scene 2: G2 requests air reconnaissance through Commander (procedures for making that request)

.
.
.

Scene N: G2 receives info requested (exit)

Figure 3-1. Example of a Script Representation: G2's Procedure for Requesting Aircraft Reconnaissance.

Frame representations have a great deal of "default" information and thus produce expectations about objects and relationships. These properties make the frame useful for data interpretation or "top-down" processing. Figure 3-2 gives an example of an object frame. Motorized Rifle Regiment (MRR) is an instance of the category, "Soviet-Force-Element." This frame is part of a hierarchy so it is part of another Soviet force element and has distinct elements of which it is comprised. Figure 3-3 shows the MRR frame in a hierarchical network, where it is subordinate to the force element "tank division" and has frames for "tank battalion" and "MR battalion" in a subordinate (HAS-PART) relationship to it.

SOVIET-FORCE-ELEMENT: Motorized Rifle Regiment

A-KIND-OF: Motorized unit

SIMILAR-TO: Tank regiment

SIZE: 4-8 Battalions DEFAULT: 6 Battalions

PART-OF: Motorized rifle division, tank division

HAS-MISSION: Conduct offensive and defensive operations on nuclear and non-nuclear battlefield as part of tank or MR Division

HAS-PART: Hdqtrs, MR BN, Tank BN

COMBAT-SUPPORT: Artillery BN, Air Defense BN, Antitank Missile BN, Recon. BN, Engineer BN, Signal BN

SERVICE-SUPPORT: Medical CO, Maintenance CO, Chemical Defense CO, Traffic Control Platoon, Supply & Service Platoon

Figure 3-2. Example of an Object Frame: Soviet Motorized Rifle Regiment.

Mental Models. Knowledge of causal processes, described at a fairly abstract and general level, can be represented in terms of mental models (M-M) (Johnson-Laird, 1983; DeKleer and Brown, 1981). Although other structures have been proposed for representation of mental models, the structure we consider here is defined as having: (1) contextual information; (2) a description of the objects that are essential to the process being described (note: if the object is a person, this description would include the person's goals relevant to the process); (3) the "forces" involved in the process, or medium of interaction between objects; (4) a description of the interaction between objects (i.e., forces acting on objects); and (5) outcomes of the process. This last part of the model would typically consist of descriptions of the impact of the process on one or more of the objects. Figure 3-4 illustrates this format with a mental model of the general concept of "conflict" between two parties.

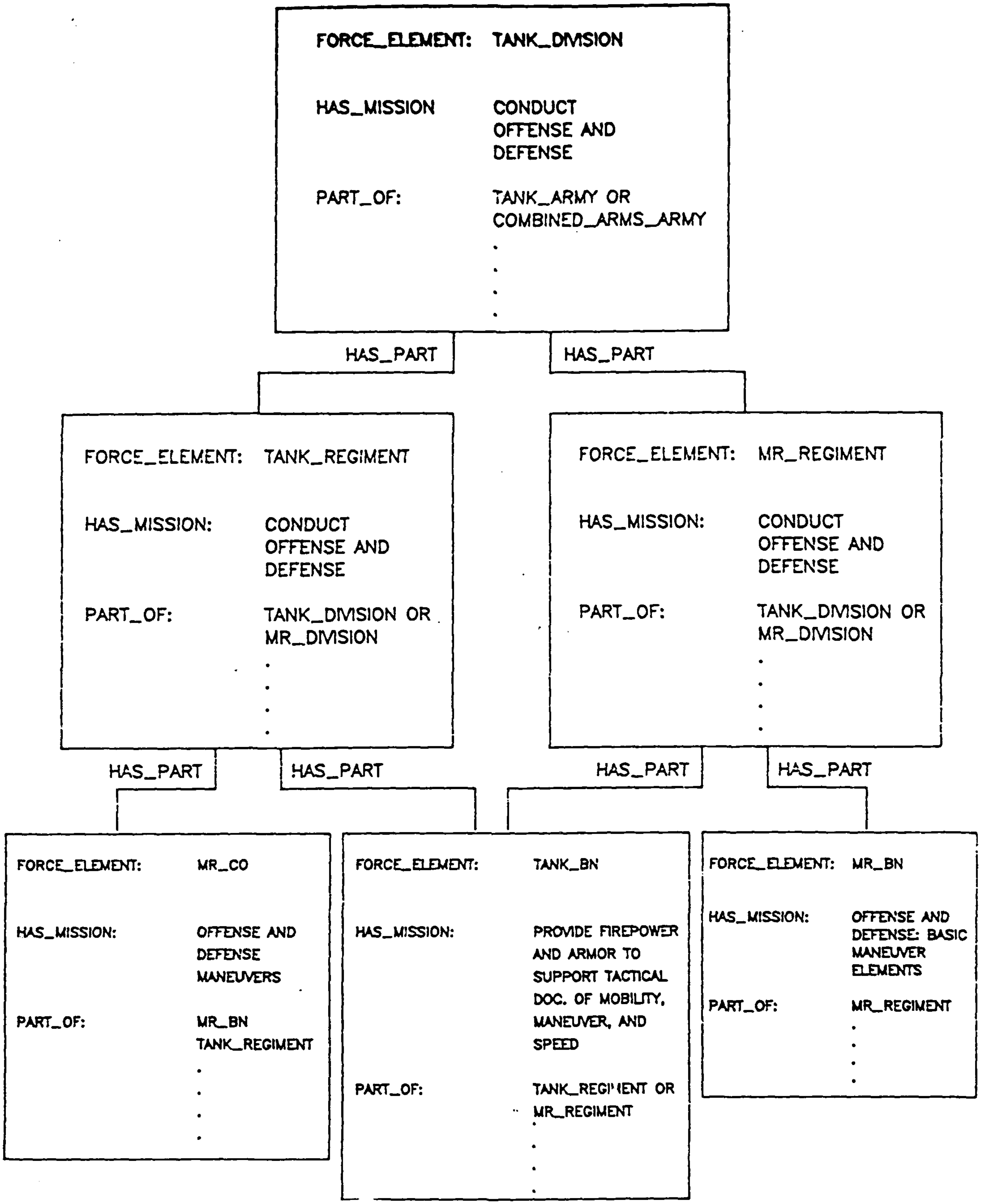

Figure 3-3. Soviet Army Frames as Part of a Network.

Contextual Information:	Red Force and Blue Force come into contact
Objects:	Red Force (goal: achieve Red objective, prevent Blue objective)
	Blue Force (goal: achieve Blue objective, prevent Red objective)
Force:	Red Force strength (property of Red Force)
	Blue Force strength (property of Blue Force)
Interaction:	Red Force strength vs. Blue Force strength
Outcome:	If Red Force strength > Blue Force strength by x %
	Then Red objective achieved, Blue objective prevented
	If Blue Force strength > Red Force strength by y %
	Then Blue objective achieved, Red objective prevented

Figure 3-4. Mental Model of "Conflict".

Integrated Interpretative Knowledge Representation. An integrated interpretative knowledge representation would utilize scripts, frames, and mental models, since each of these approaches to knowledge representation has, despite some shortcomings, its own individual strengths that are rather complementary to the characteristics of the other two structures.

The strength of script-based representations is that they describe sequences of events in a goal-related fashion and they are expectancy-driven. This quality is useful in representing problem solving behavior based on standard operating procedures and Army doctrine. The weaknesses of script representations are three-fold. First, scripts provide a static as well as stereotypic description of processes and thus do not capture the knowledge used to guide problem solving in dynamic or novel situations. Second, scripts frequently involve the use of objects while not directly containing information about them. For example, a script involving the conduct of a battle may refer to the positioning of battalions without describing what a battalion is. A third weakness of scripts is that while they are goal-directed in nature, the causal relationship between the actions followed and the desired goals is not explicit. For example, the battle script may include a "supply" scene, although how this helps fighting the battle is typically left out of the script. Frames and mental model representations can help compensate for these shortcomings, however. Frames are a useful representation tool for capturing information about the objects (e.g., objects that are part of

scripts). Mental models can provide a good vehicle for representation of dynamic-process abstractions as well as the causal relationships between problem-solving goals and actions.

An integrated interpretative representation scheme can thus be constructed using scripts, frames, and mental models, building on the complementarity of these structures. The structures would be linked by pointers.

Emphasis on the use of one structure versus another will greatly depend on the nature of the problem solving in a particular domain. For example, problem solving that is more object-oriented would probably involve a predominant use of frames while problem solving involving a rather standard and consistent set of procedures and problem situations could be represented largely in terms of scripts. In domains where the observable features of problems can vary greatly, but the set of possible underlying causal processes is finite, the approach to representation likely to dominate would be mental models.

3.2.2 Generative knowledge structures. Structures that appear most amenable to representation of an expert's knowledge for bottom-up processing are production rules, semantic nets, and highly constrained (i.e., very detailed) mental models. These structures respectively serve to address the questions of "How?" "What?" and "Why?" at a very concrete and specific level.

Production Rules. Rule-based knowledge *representations* consist of a situation-recognition part and an action or implications (for inference) part (Newell and Simon, 1972). This is typically expressed as an IF-*condition*-THEN-*action* statement. When the current problem situation satisfies or matches the IF part of a rule, the reasoning or action specified by the THEN part of the rule is applied or performed (Nilsson, 1980). The condition portion of a production rule can contain compound events, connected by AND and OR. Figure 3-5 offers some examples of production rules that might be part of the knowledge base of an Army intelligence expert.

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A Coded Example:

```
(1)   IF     ((friendly-unit-loc) minus (enemy-unit-loc)) < =
             (friendly-artillery-range)
             AND   (enemy-unit-x-status) = (uncommitted)

      OR     (enemy-unit-x-status) = (stationary)
             AND   (friendly-enemy-contact) = (not reported)

      THEN   (enemy-unit-x-status) = (advance-to-contact)
```

A Written Example:

```
(2)   IF     enemy unit X assumed to be advancing to contact

      THEN   identify intelligence sources Y capable of observing
             enemy unit X
      AND    Request intelligence on enemy unit X from all sources Y
```

Figure 3-5. Production Rules Examples.

A sequence of production rules can produce an *inference chain* that can serve to make inferences, by forward-chaining, or deductions, by backward-chaining. Figure 3-6 shows an AND/OR tree of production rules and inference chains.

Forward-chaining involves inferring general implications from specific information. For example, specific conditions such as "current assessment of enemy status is that the enemy is stationary at some location X" and "location X is within friendly artillery range" will lead to a more general condition--that the enemy situation assessment needs to be updated and perhaps revised. Backward-chaining involves just the opposite; the statement of a general condition implies the pre-existence of some more specific conditions. A recognized need to update or revise the enemy situation assessment indicates that the current one is perhaps obsolete, which in turn may imply that the time lapse from the previous assessment update is more than 1 hour; it implies that the current assessment appears implausible in the light of some new information, such as the main attack has been projected along corridor A but the ratio of enemy-to-friendly forces along corridor A is much less than that required by Soviet doctrine for a successful attack.

Semantic Nets. Repeated observation of objects and events with similar features leads to the formation of categories, classes, and types--of objects, events, and people. One representation of this sort of knowledge is a *semantic net*. Semantic nets, originally developed as psychological models of human memory (Quillan, 1966; Rumelhart, Lindsay and Norman, 1972) consist of points, called nodes, connected by links, called arcs, which describe the relationships between nodes. The nodes in

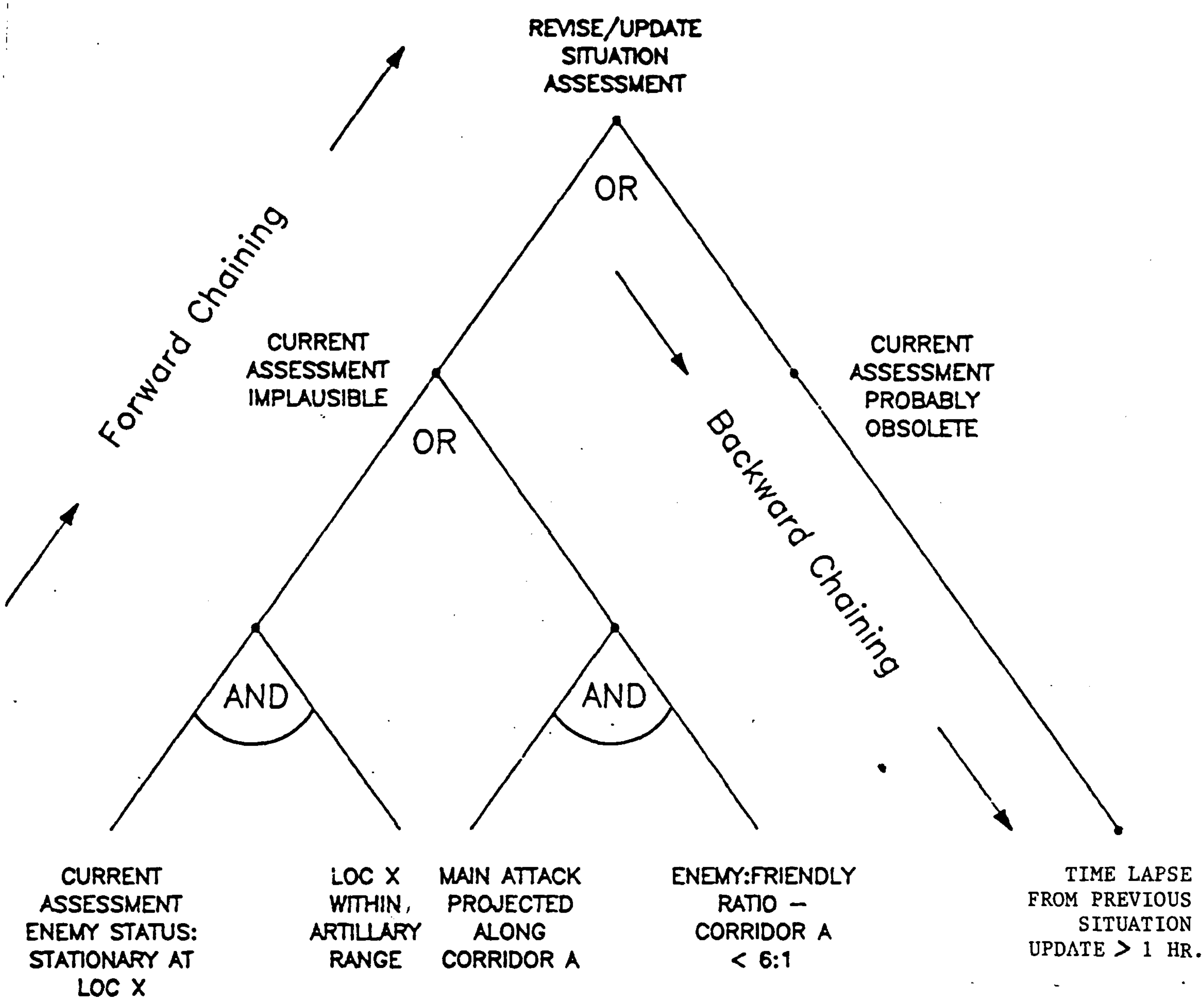

Figure 3-6. And/Or Tree of Rules.

a semantic net stand for objects, concepts or events. Common arcs used in representing hierarchies are IS-A and HAS-PART.[1]

Figure 3-7 shows a simple semantic net representation of "the Abrams is a tank" and "a tank is an armored vehicle." Since the IS-A relation is transitive, we can infer that the Abrams is an armored vehicle. Thus, relations such as IS-A and HAS-PART establish a property *inheritance hierarchy* in a semantic net. This is illustrated in Figure 2-8 which expands on the previous example. In this case, several different bottom-level object nodes can be traced up to the object, "armored vehicle." A gun turret is part of a tank; the link HAS-PART is thus top-down. On the other hand, "Abrams" is an instance of the category, Tank, and the IS-A link is bottom-up. "Bradley is an instance of an armored personnel carrier." Tank and Armored Personnel Carrier are upward-linked instances of the broader category, Armored Vehicle. Armored Vehicle has various features that will uniquely identify it. These include Engine and Road Wheels, linked top-down with a HAS-PART connector from Armored Vehicle. The object mode, Engine, in turn, HAS-PART Cylinders among its various constituents (n.b., an analogous connector flowing bottom-up would be PART-OF). Semantic nets are a useful way to represent knowledge in domains that use well-established taxonomies to simplify problem solving (Waterman, 1986).

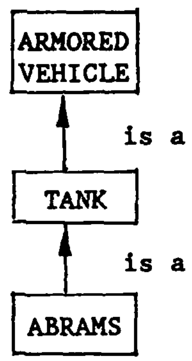

Figure 3-7. Semantic Net Representation.

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1. Semantic nets used to describe natural languages also use arcs such as *subject*, *object*, and *relation* (Anderson, 1980).

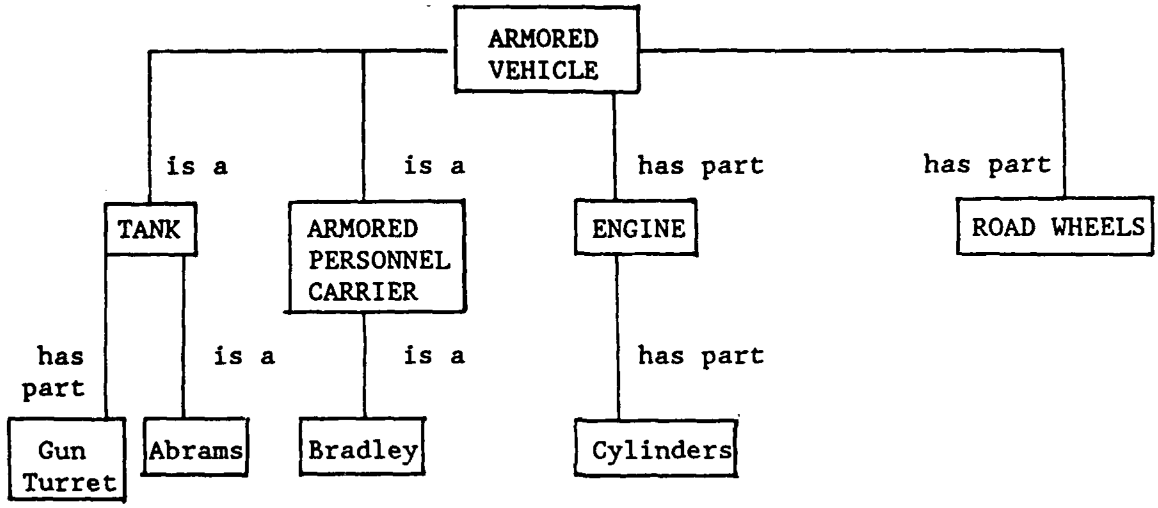

Figure 3-8: Semantic Net Representation of Bottom-Level Object Nodes

Highly Constrained Mental Models. In the section describing interpretative approaches to methods of knowledge structuring, we introduced a construct for the representation of causal knowledge, which we called a *mental model*. It was defined as having: (1) contextual information; (2) a description of the objects that are *basic to the* process being described; (3) the "forces" involved in the process, or medium of interaction between objects; (4) a description of the interaction between objects (i.e., forces acting on objects); and (5) basic outcomes of the process.

This representation format can be used not only for abstract-level and broadly specified processes, but for more concrete and narrowly specified processes as well. Figure 3-9 illustrates a mental-model representation of the process of interception of electronic signal communications.

Integrated Generative Knowledge Representation. The integrated generative knowledge representation scheme utilizes all three of these generative approaches to knowledge structuring (i.e., production rules, semantic networks, and mental models). This approach to the representation is essentially production rule-based, however, since production rules are used in, and are well-suited to, a wide variety of problem-solving and decision-making domains. The integrated approach to representation is designed to capitalize on the strengths of these three different knowledge structures while minimizing their collective shortcomings. The strength of production rule-based representations is that they are action-oriented and lend themselves well to problem-solving and decision-making domains. The weaknesses of such representations is first, their inability to describe the objects or processes to which they refer; and second, their inability to convey an underlying rationale for the *actions specified* by the rules when required conditions are met. The first shortcoming can be addressed by linking the objects specified in

Contextual Information:	Battlefield with Electronic Communications
Objects:	Enemy 1 (goal: send message to E2) Enemy 2 (goal: receive message from E1) Friendly ELINT operator (goal: receive message from E1) E1 electronic communications equipment (E1-equip.) E2 electronic communications equipment (E2-equip.) FE electronic interception equipment (ELINT-equip.)
Forces:	Electronic Signal
Interaction:	E1 sends message to E2 using E1-equip. (ref: model of human-elec. comm. equip. interaction) (ref: model of signal transmission by elec. comm. equip.) E2 receives message from E1 using E2-equip. (ref: model of human-elec. comm. equip. interaction) (ref: model of signal reception by elec. comm. equip.) FE receives message from E1 to E2 using ELINT-equip. (ref: model of human-elec. intercept. equip. interaction) (ref: model of signal interception by ELINT equip.)
Outcome:	E2 has data from E1 FE has data from E1

Figure 3-9: Mental Model of Interception of Electronic Communication

rules to a semantic net of information and relationships. The latter problem can be ameliorated by inclusion of mental models. Mental models are viewed here as causal representations for how both particular physical or conceptual (e.g., arriving at an insight) events occur. As such, these models can offer a direct justification for the implementation of specific procedures under a given set of conditions. Having the expert subsequently perform specific problem solving would then serve to flesh out the procedures that he would actually use and how they are guided by his broader objectives.

4.0 ELICITATION TECHNIQUES

4.1 Knowledge Elicitation: The Pool of Candidate Methods

A variety of potentially useful methods of elicitation were reviewed in the process of selecting and tailoring methods to meet the elicitation goals of our integrated knowledge frameworks. Some of these are typically used in the current development of expert systems, while others derived from the current array of research methodologies used in cognitive psychology.

Although a number of techniques for the acquisition of expert knowledge have been referred to in the literature on expert systems, there has hitherto been little detailed documentation of their actual use, reliability, and relative effectiveness. Some methods are more observational in that the elicitor does not interrupt or otherwise interfere with the expert's problem-solving processes, which are used to handle realistic problems. But most knowledge-acquisition techniques require that the knowledge engineer play a more active role in an effort to get new facts and rules, or clarify or validate existing ones (Waterman, 1986).

The techniques that a knowledge engineer might typically use to extract knowledge from a domain expert include (Waterman, 1986):

- on-site observation;
- problem discussion;
- problem description;
- problem analysis;
- system refinement;
- system examination;
- system validation.

On-site observation requires watching the expert solve real problems on the job. *Problem discussion* involves an exploration, in an interview between the elicitor and expert, of the kinds of data, knowledge, and procedures needed to solve specific problems. *Problem description* entails having the expert describe a prototypical problem corresponding to each of the basic solution strategies identified by the expert as being commonly used in that domain. *Problem analysis* refers to methods in which the expert would be given realistic problems and be asked to think aloud while the elicitor periodically interrupts this process to probe for the rationale behind the expert's reasoning.

The remaining methods require that a prototype be developed and used as part of the elicitation process. *System refinement* thus involves having the expert supply problems for an expert-system prototype to solve using rules acquired during earlier elicitation sessions. *System examination* entails having the expert examine and critique the prototype system's rules and control structures. *System validation* is defined (Waterman, 1986) as involving the presentation of cases solved by the expert and the prototype system to other outside experts for review.

The use of a prototype for "knowledge engineering" (i.e., knowledge elicitation for building expert systems) is rather common, and "rapid-prototyping" is a system-development strategy that has been advocated by a number of influential AI researchers (Hayes-Roth, Waterman, and Lenat, 1983). While there are some advantages, there are also disadvantages to this approach to knowledge elicitation. While it does provide a tangible and specific example of the kinds of abstract goals, objects, and strategies that have been talked about, helps the elicitor better comprehend the problem domain, and provides a focus for discussions between elicitor and expert, the rapid prototype can also serve as a rather spurious anchor that biases the direction of subsequent knowledge-elicitation work toward extension or refinement of the prototype's knowledge base. The prototype can also predetermine the approach to knowledge representation that is taken in the final version of the system by virtue of the availability of its knowledge representation, regardless of the ultimate appropriateness of the approach taken in the prototype software.

Knowledge acquisition that emphasizes the use of a rapid prototype is much in keeping with the overall approach to knowledge elicitation adopted by AI researchers, however. To this community, "knowledge" refers to the information a *computer program* needs before it can behave intelligently (Waterman, 1986), so elicitation focuses on what computer programs need to solve problems rather than on what human experts actually use to solve problems.

Approaches to elicitation from cognitive psychology have the reverse emphasis since this field is primarily concerned with human knowledge and how it is organized, as well as its contents. Methods that are potentially useful for expert-knowledge elicitation include:

- directed interview
- memory recall and reconstruction;
- cloze experiments;
- multidimensional scaling and sorting experiments;
- personal construct methods;
- protocol analysis;
- direct observation.

Directed interview techniques involve asking the expert rather broad questions about the problem domain, followed by questions to pursue more detailed description of the objects and processes referred to in the expert's earlier responses. This method is useful in development of a broad framework for domain knowledge, and should be effective in elicitation of high level knowledge.

Memory recall and reconstruction techniques can be applied in a variety of ways. For example, the elicitor could have the expert try to remember episodes of his past problem experiences in the domain in question. The details of remembered episodes may inform the elicitor as to what features of the domain are important and what features organize memories, and thus knowledge (Anderson, 1980). One difficulty with the variation, however, is that the unstructured nature of experts' responses may impede its being cast in a more meaningful structure that essentially captures the experts' own representations of the domain.

Another form of the recall and reconstruction method that would impose more constraints on experts' responses would be to present them with probe episodes and ask them to recall any similar ones. In this case, commonalities between the probe and the recalled episode might indicate how this information is organized in memory.

An even more structured use of the recall and reconstruction method would involve experts reading descriptions of problem episodes relevant to their domain and then trying to recall what they've read. Studies have shown that people can best recall *information* which is consistent with the knowledge they already have about the domain, and will often erroneously recall information which was not present in the material they just read, but is typically associated with the case they have read about.

Cloze experiments require that experts either recall or construct information. The recall task is generally more constrained than in the use of recall and reconstruction methods. In cloze experiments, subjects are given materials which are incomplete (e.g., a word may be missing in a sentence or objects or events may be missing in a list or sequence) and are asked to complete them. Subjects'--in this case, the experts'--choices of what to fill in should reflect what is anticipated and is thus a useful vehicle for capturing information organized by, or in association with, these objects (cf., Bower, Black and Turner, 1979; Seifert, Robertson and Black, 1982; Smith and Collins, 1981).

Multidimensional scaling and sorting experiments are methods that could be used to elicit factors that mediate perceived similarity among pieces of knowledge. Such methods have been used to measure similarity among different semantic concepts (cf., Rips, Schoben and Smith, 1973), and sorting experiments have been used to identify shared themes across event sequences. A shortcoming of these methods, however, is that although they may reveal features that determine similarity, they do not reveal directly why these features are the critical ones, or what functions these features serve in relation to other features of the domain.

Personal construct methods entail elicitation of knowledge in the particular form of "constructs" which represent strongly contrasting concepts along comparable dimensions (e.g., Kelly, 1963), which are organized hierarchically, like frames or schemas. As such, they can be elicited using a variety of methods. For example, an elicitor might ask the expert to describe both a "very good" solution and a contrasting "very poor" solution to a particular problem.

Protocol analysis refers to the analysis of think-aloud protocols of expert problem solving (Newell and Simon, 1972). These protocols are obtained during an elicitation session in which the expert is given a specific domain problem and is asked to "think aloud" as he goes about solving it. Although there are detractors of this elicitation approach who contend that people are not directly aware of, and cannot accurately describe, their internal information processing (Nisbett and Wilson, 1977), it also has strong supporters (Ericsson and Simon, 1984) who argue that the concurrent (with the behavior under investigation), particular (i.e., tied to the specific task being done), and undirective (i.e., the elicitor does not interrupt or try to influence the course of problem solving) nature of this elicitation method offers the best available means for constructing accurate models of expert knowledge.

Direct observation is the least obtrusive and thus, perhaps, the most natural approach to knowledge elicitation. Employing this method, the elicitor would give the expert a realistic problem, or observe the expert solving problems in "real-world" task environments. Although this method assures that the process of elicitation does not in any way affect the expert's problem-solving behavior, it has the corresponding drawback of forcing the elicitor to make very substantial inferences about the expert's knowledge and precisely how it is used to direct the behavior being observed. This method is most effective when there are other domain experts, including perhaps the person doing the elicitation, who can provide a fairly accurate account of the expert's actions.

Many of the elicitation methods used by knowledge engineers could actually serve to tap the same object and process knowledge as the methods from cognitive psychology, and may thus suit the data collection needs of this project. What is quite different is the way elicited knowledge would be used by knowledge engineers. Most expert system builders will encode data from knowledge elicitation into forms that are compatible with their system architecture's predefined requirements. By contrast, we propose that knowledge elicitation proceed in ways that are compatible with how the expert represents them.

The same techniques might thus be used to serve two distinct elicitation perspectives each with a different flow of control in elicitation. The system builders' approach to elicitation involves (1) determination of system requirements based on a preselected structure for knowledge representation; (2) elicitation of the expert knowledge; and (3) coding the knowledge into the system's representation. The alternative approach that we explore involves (1) determination of the knowledge an expert would use to perform the task; (2) selection of the elicitation methods compatible with an expert's approach; (3) development of models of the expert's knowledge; and (4) evaluation of the quality of these models and methods.

4.2 Interpretative and Generative Methods of Knowledge Elicitation

From the pool of elicitation techniques described above, techniques can be packaged to form a methodology of knowledge elicitation that assumes an underlying model of knowledge representation and expert problem solving. Below we offer a demonstration of two such methodologies. One assumes that expert knowledge and problem solving is organized in a "top-down" or interpretative fashion, while the other assumes that expert knowledge and problem solving is organized in a "bottom-up" or generative fashion. Additional techniques can be used to supplement the primary techniques of the methodologies.

It should be noted that in constructing these methodologies, two principles are operating; first, the first half of the elicitation session is structured and constrains the expert's responses, while the second half is less structured (once the framework has been set). Second, the first technique used on the expert is geared toward eliciting knowledge at the level of abstraction that the method assumes will be the organizing principle. Specifically, the interpretative method starts with a technique which is designed to obtain high-level, general knowledge (i.e., interview), while the generative method starts with a technique which is designed to obtain low-level, specific knowledge (i.e., problem solving). As the elicitation session proceeds, the techniques change to induce a "top-down" or "bottom-up" flow of knowledge for the interpretative and generative method, respectively. The initial structure placed on the expert is designed to "force" the expert into an interpretative or generative *mode*.

By forcing the experts into one of these modes, the elicitor can control and insure that each method is inducing a corresponding knowledge use and flow of knowledge control from the experts. Once these modes have been thrust on the experts, the elicitor can compare interpretative and generative methods of knowledge elicitation for their efficacy.

4.2.1 Interpretative method. An assumption underlying our interpretative method is that expert knowledge is organized in a "top-down," hierarchical fashion. By this we mean that knowledge is organized around high-level goals and plans, which in turn index more low-level procedural and content knowledge. This can be viewed as analogous to deductive reasoning, where reasoning proceeds from general to specific cases.

Our interpretative elicitation method prescribes that knowledge elicitation should occur in an interpretative method, i.e., by first eliciting general knowledge, primarily focusing on goal and planning knowledge and successively refining this knowledge until specific procedures and content knowledge are elicited. Two knowledge elicitation techniques form the heart of this method: structured interview and "top-down" problem solving.

Structured interview. A structured interview is a question and answer-type procedure where the elicitor asks the expert a series of questions and follow-up questions which are specifically designed to build certain knowledge structures. Questions are therefore guided by the

specific structures the elicitor is trying to build and the slots that are contained within those structures.

While a structured interview is a general technique which can be adapted to elicit knowledge concerning a variety of knowledge structures, we discuss how this technique was used in the interpretative method. However, knowledge elicitors could readily adapt the interpretative version of the technique for elicitation methodologies.

In the interpretative method, the structured interview is used to elicit script-based and supporting knowledge (i.e., frames and mental models which supplemented the script-based knowledge). As such, this induces experts to use their knowledge in an interpretative fashion, since the elicitor largely directs what knowledge the expert provides and when (as will seen below). In order to accomplish this, the elicitor takes his script template and uses each slot as a basis for generating questions. The details for doing this are outlined below.

The elicitor designates which initial script he is going after by the domain area (e.g., situation development, order of battle). For the sake of illustration we will assume that the elicitor is interested in knowledge pertaining to situation development. The first slot on the script template is *tracks*, i.e., major conditions which dictate variations in the way the script is executed. Hence, the elicitor begins by asking the expert if there are any conditions which might influence they way situation development is carried out. If the elicitor is able, and the expert is having trouble either understanding the question or coming up with an answer, he might prompt the expert by giving tentative examples. These examples should be general enough so as not to bias the expert too much, but sufficiently relevant to be a useful prompt. In this case, a useful prompt might be (and one that was used in the present knowledge elicitation), "for example differences in echelon or level of conflict?".

Once the elicitor has specified what the different tracks are, the elicitor should get examples of each (for example, if situation development is different depending upon level of conflict, then the elicitor should get examples of the different levels of conflict, e.g., high intensity vs. low intensity conflicts). The elicitor should then ask the expert to describe how situation development is different based on these different tracks. This question may lead to knowledge that is more appropriately associated with other slots in the script. However, it gives the expert a chance to present knowledge that may be stored at this more general level as opposed to stored with the specific slots.

Once the elicitor has exhausted his questions regarding tracks, he proceeds to the next set of questions. Between the tracks slot and the slots holding information regarding scenes and actions, there are slots that are basically containers of background and contextual knowledge. These slots include goals (e.g., the goals or objectives behind doing situation development), the entry conditions (conditions which trigger execution of the script), roles (the people that are relevant to the script either as participants or because they interact with the script in some meaningful way), props (the tools and objects that are relevant to the script), and outcomes or results (the state of the world that results

when the script is executed, particularly how it relates to the goals of script, i.e., which goals get satisfied and which goals do not).

For each of these slots, the elicitor asks an appropriate question, e.g., "What goals or objectives are you trying to achieve when you perform situation development?". The elicitor should be prepared to rephrase these questions in case the expert is unclear as to what the elicitor means or is interpreting them in the wrong way. For example, the elicitor may want to say "Who are the relevant people involved or with whom do you interact?" for the roles slot. Of course, in trying to clarify the question, the elicitor should be careful not to constrain the experts answer. For example, the relevant roles of the script might go beyond those that the expert interacts with. Therefore, after the expert gives his answer, the elicitor should be prepared to ask a follow-on question such as "Is there any one else who affects what you do, even if you don't interact directly with them?". If the elicitor could give some examples, even if they are wrong, it may help to prompt the expert, e.g., "For example, the Corps commander or the enemy forces?".

Below, we present sample questions for these slots along with alternative ways of asking them and generating follow-ups.

Goals: "What are your goals and objectives in doing situation development?" "Why do you do situation development?" "What are you trying to accomplish or achieve?"

Entry Conditions: "*What conditions trigger your doing situation* development?" "When do you do situation development?" "Is it an ongoing process or does something occur to trigger the process, like a change in the battle or an order from your commander?" "Is there any other set of circumstances that might trigger it?"

Roles: "What people play a role in doing situation development?" "With whom do you interact?" "Are there any people you don't interact with but still influence what you do, like the enemy forces?"

Props: "What kind of tools or objects do you work with?" "If I were to walk into your shop, what kinds of things might I find there or see you working with?" "Do you have things like maps, reference books and workbooks?"

Outcomes: "When you've completed situation development, what have you accomplished?" "What outcomes occur as a result of doing situation development?" "What do you know as a result of doing situation development that you didn't know before?"

As these questions are being asked, it is useful to tie them to the particular tracks that have been laid out before. Hence, the elicitor might ask questions like, "In a low intensity conflict are the players any different than in a high intensity conflict?" or "Do you work with different tools at battalion level than at division level?", etc.

It should be noted that during the elicitation, the expert will undoubtedly make references to concepts or objects that are relevant to the script. Such references are probably most likely to occur when eliciting knowledge regarding roles and props. For example, in describing the enemy forces, the expert may make reference to "motorized rifle division". When such references occur, the elicitor must know what they are and what their role in the script is. In order to answer these questions they elicitor should attempt to elicit an object frame about that concept. The method for doing so is analogous to the method for eliciting scripts. The elicitor takes the general template for an object frame and uses each slot as a basis for generating questions. For example, for the "ISA" slot, the elicitor might ask, "Is there a more general category that (e.g.) a motorized rifle division is an example of?"

Once the background knowledge has been elicited, the elicitor then focuses on the heart of the script, namely the scenes and the actions. The boundaries between them may not always be clear. In section 7, we discuss how to distinguish between them. Proactively, an elicitor may attempt to elicit information that will help him decide later what the scene boundaries are (e.g., information regarding the setting associated with different actions, the people involved and the objectives in relation to the overall script) by asking questions designed to get at such information, e.g., "Where are you when you're doing this?", "Who is with you?", "What is the purpose of doing this?", and "Is this action and the previous one part of the same procedure?".

In order to elicit the action relevant knowledge that will fill in the script, the elicitor asks the expert to give a step-by-step outline of the procedures he follows in performing the script. After the expert goes through the process, the elicitor can recursively ask the expert to provide additional details, to fill in specific actions. For example, if the expert is describing situation development and says "First, I get a briefing from the officer that I am relieving. Then I do a terrain analysis. Then I look at the order of battle data, etc.", the elicitor may wait until the expert is through and ask questions like, "How do you do the terrain analysis?". After the expert describes that, the elicitor can repeat the process, e.g., "How do you determine what blocking terrain is?", "How do you decide if the river is fordable?", and so on until the expert cannot specify the knowledge in further detail.

While the elicitor is eliciting the scene and action knowledge, he may wish to elicit mental model-related knowledge which explains why the particular actions are being performed. These models will probably link actions to the scene-related goals and scenes with script-related goals. For example, the action of marking blocking terrain on the map serves the scene (terrain analysis) related goal of determining where the enemy can and cannot go. The terrain analysis scene serves the situation development script goal of inferring what the enemy course of action will be (where the terrain analysis provides inputs of what enemy courses of action the terrain can support).

We advocate a two-step process for eliciting mental model-related knowledge. First, the elicitor can ask the expert a "Why?" question regarding the procedure he is describing. The expert is then allowed to

describe in an open-ended format the reasons for the procedure. The elicitor tries to supplement this answer by asking questions specifically designed to elicit knowledge relevant to the slots of a mental model. For example, the expert might be asked, "What are the objectives behind this?" or, in "What context would this occur" (a variant of this, to get at the level of generality, might be "Is this a universal principle or does it apply only to specific cases?"), etc. The elicitor can focus the expert on particular goals by asking questions like, (e.g.) "How does doing terrain analysis help you to predict the enemy course of action?". In fact, in principle, the elicitor can relate any action to any goal in the script and elicit a mental model for it. The elicitor must decide to what extent to pursue this.

The above is a description of the structured interview technique. There are some general issues the elicitor must keep in mind. First, the elicitor must decide in what depth to pursue the expert's knowledge. Since this technique can be used recursively, the elicitor could keep going until the expert cannot answer or gets annoyed. The elicitor must decide what objectives he has and how this affects the degree of detail necessary to be elicited.

In order to make a judgment on this, the elicitor should consider the following trade-offs: forcing the expert to elaborate on everything may distract his train of thought and sacrifice some of the points the expert was trying to make. For this reason, it is recommended that the elicitor waits until the expert exhausts what he was going to say and then go back to the point where more depth is desired. If possible, we advocate that the elicitor pursue a train of thought in depth before proceeding to the next train of thought, rather than covering all the topics at the same level of detail and then proceeding to the next. To rephrase this, we advocate eliciting in depth first rather than breadth first, unless the expert spontaneously gives knowledge in a breadth-first fashion.

Second, the elicitor should try to safeguard against missing knowledge that the expert has. While it is probably impossible to insure against some misses, there are some steps that the elicitor can take to try to get a complete elicitation. First, the elicitor should try to avoid interrupting the expert and allowing him to finish his answer before proceeding to the next question. If in doubt, the elicitor should ask the expert if he's finished. Second, the elicitor can ask questions like, "Is there anything else you can think of?," "Is there some other situation where things might be different?". If the elicitor can actually generate some sample situations this may be helpful.

When the elicitor has completed the interview to his satisfaction, he is ready to proceed to the top-down problem solving technique.

Top-down Problem Solving. Top-down problem solving is a technique which is very useful in a supplemental capacity to an interview technique, particularly a structured interview. In a capsule, this technique involves giving experts problems to work on and observing and recording their performance. The elicitor is particularly interested in comparing how the expert actually solves a concrete problem to how he describes the problem solving approach in the more abstract interview. Hence, the

elicitor should be prepared to ask questions to link the two techniques together and to integrate the knowledge produced by the problem solving technique with the knowledge produced by the interview.

The top-down problem solving technique is more unstructured than the structured interview. As such, this technique should not bias the expert to use his knowledge in an interpretative or generative fashion. In order to conduct this technique, the elicitor must have available a problem which is similar to the kind that the expert typically works on. This will include all the background information as well as the tools and reference materials that the expert will need to solve the problem. Hence, this technique requires much preparation. If the expert is used to having human resources available when solving the problem, it will be very useful to have such resources available. This can be done in several ways. If possible, the expert can solve the problem in a group setting with the other group members playing the roles of the people the expert normally works with. This is probably the most difficult solution to arrange. If the elicitor is sufficiently expert in the subject matter area, he can play the role of the additional people. This may be undesirable if the additional people would normally be co-problem solvers as opposed to repositories of information, as participation would probably distract the elicitor from conducting effective knowledge elicitation.

A third alternative, possibly the best one, would be for the elicitor to have a subject matter consultant who is familiar with both the domain in question and the elicitor's objectives. Such a person could provide the human resources that the elicitor needs in a way that won't obstruct the elicitation process. If the elicitor lacks subject matter expertise, then it is important that a separate subject matter expert serves as the co-elicitor rather than having the subject himself play that role. First, having the subject participate as an elicitor (e.g., trying to anticipate when explanations are going to be necessary or determining the level of complexity to focus on) may disrupt the expert's natural reasoning processes and spoil the elicitation session. Second, if the subject perceives that the elicitor is naive, he may discuss topics at an elementary level rather than at an expert level. Having a subject matter expert as a co-elicitor may encourage the subject to speak at expert levels. Other advantages of the subject matter consultant are that he can provide the background to the problem and answer clarifying questions, and also having such a consultant may put the expert at ease (i.e., the expert feels that there is one of his "kind" there) and may add credibility to the elicitor in the eyes of the expert.

The expert is given an overview to the problem and asked to solve it. The elicitor should be precise on what the expert's goals should be (e.g., "Give a briefing on where you think the enemy main attack will come.") and be informed as to what resources the expert can use and will have available. Since problem solving is often a basis for performance, it is important to assure the expert that he is not being evaluated and that the elicitor is interested in the expert's process, not the correctness of his answer.

The primary source of data will be inferences drawn from observation and having the expert explain what he is doing. Hence, the elicitor

should ask the expert to think aloud as he is working on the problem and explain what he is doing. The expert should be told that the emphasis is on process and that expert should try to articulate the process as well as possible. It is important to note that not all experts will feel comfortable doing this, since most experts are probably used to working silently and may not be used to explaining problem solving processes to others (for this reason it may be useful to screen experts, e.g., find some who have taught the material and hence are used to explaining the process). If this is the case, the elicitor may have to play an active role in trying to get the expert to talk. One way to do this is periodically to urge the expert to verbalize, particularly if he is going for periods of time without speaking.

Another method is useful, particularly if the expert is having trouble simultaneously articulating and working on the problem (this would be indicated by long periods of silence where prompting does little good). This method involves stopping the expert periodically and asking him to describe what he had been doing. We have found that this method works very well. It is important, however, to stop the expert after he has completed a sub-task, i.e. seems to have paused or is changing procedures. Examples of this might be after the expert has stopped analyzing a map, after he has stopped reading a manual, etc. It is important to try not to break the expert's train of thought while he is working on the problem.

In general, the elicitor provides less direction, so as not to interfere with how the expert wants to solve the problem. The elicitor should restrict his questions to those of a clarifying nature (e.g., "Could you explain what you just did there?") or trying to link what the expert is doing to what he said earlier in the structured interview (e.g., "Are you doing the terrain analysis that you described in the interview?"). The elicitor should try to ascertain how the expert is solving the problem. To do this, he may need to ask questions like "What information are you looking for/using?", "What hypotheses have you developed?". Such questions may relate back to answers the elicitor gave earlier (e.g., "Earlier you thought the enemy might be attacking in the north. How does this new evidence relate to that conclusion?").

The elicitor must determine the timing of particular questions. Questions that may lead to general discussions are probably best left for periods reserved for summaries of what the expert has been doing. However, specific questions like "What information are you looking for?" need to be timed to when the expert is actually looking for it.

4.2.2 Generative method. Contrasting with the interpretative method of knowledge elicitation is the generative method, which is based on the assumption that knowledge is organized in a "bottom-up" or generative fashion. By this we mean that knowledge is organized around low-level situation specific rules and content knowledge which gets accumulated from concrete experiences and is then generalized to higher levels of abstraction. The principle containers of such knowledge might be production rules, semantic nets and mental models which capture the how, what and why aspects of knowledge, respectively.

The basic philosophy behind the generative method is to try to capture knowledge that centers around specific procedures (both for executing actions and making inferences) and specific objects and/or concepts. As this knowledge is accumulated, the elicitor attempts to link the individual pieces of knowledge together by chaining and also attempts to generalize the knowledge by eliciting higher level rules and more general categories of concepts and objects. Hence, a complete knowledge base is built from "the bottom up".

Like the interpretative method, the generative method has at its heart two primary techniques, interview and problem solving. However, these techniques have been adapted for use in a generative strategy of knowledge elicitation. Similarly, the order of administration has been reversed with problem solving occurring first and interview acting as a supplemental technique. This ordering relates back to our notion that problem solving as a technique is best suited for eliciting specific and more low-level knowledge while interview as a technique is best suited for eliciting general and more high-level knowledge.

We discuss our generative problem solving and interview techniques below. We should note that in practice these techniques are not as discrete as in the interpretative method. Rather the techniques overlap with problem solving being emphasized in the initial stage of the elicitation, but once a significant knowledge base has been built up, the problem solving technique gets phased out while the interview technique is phased in to attempt to build generalities and linkages from the lower level knowledge.

Data-driven problem solving. This problem solving technique has been developed for the generative method (Leddo and Cohen, 1987). It is one which induces the expert to solve a problem in a generative manner (i.e., the flow of control of the expert's problem solving is made to be generative). The purpose behind inventing the technique was the observation that people very often have unspoken assumptions they make that influence their judgments and conclusions. Such assumptions are typically derived from the context the problem is in and can mislead an elicitor's perception as to how the expert is reasoning. Even asking an expert to state his assumptions is often inadequate since an expert may not realize all the assumptions he is making or take many of them for granted and not bother listing them.

The data-driven problem solving technique tries to control for these background assumptions as much as possible. Hence, the data-driven problem solving technique requires careful control of the information that the expert has available. We realize that it is impossible to completely control for all assumptions experts can bring to bear.

The data-driven problem solving technique requires that the elicitor has a problem available, one that has a lot of data, which when taken together, can lead the expert to some solution (although a more limited use of this technique can be achieved by having random pieces of data). Hence, this technique is most useful in problems or domains that lend themselves to building solutions to problems from individual pieces of data. The technique begins by giving an expert a single piece of datum,

which could be in the the form of a message or a spot report that he might see while working at his job. No other information is provided, i.e., the expert does not know where he is fighting, at what echelon, who the enemy is, what day of the war, etc. Admittedly, this is highly artificial in that the expert would have extensive background information in a realistic situation. However, the point of this technique is not to have such background information color the expert's answer.

After the expert has looked at that information, he is asked four basic questions: "What does this data mean to you?", "What assumptions or conclusions have you reached as a result of this?", "Can you link this information with other information that you have seen? (assuming the expert has seen other)", "If you had additional information, what would it help you to conclude?". While it may seem as though an expert would have great difficulty answering such questions, as can be seen from the annotated protocol presented in section 7, experts are able to give a lot of information with limited data to go on.

The first question, what the data means to the expert, is basically designed to get a dump of all the inferences that the expert can generate. Hence, this question elicits knowledge in breadth what the expert knows that relates to the data. Our experience with this technique suggests that experts are able to give quite a lot of knowledge even with such relatively little prompting (and in spite of the fact that the presentation of the data is in a format that is unusual for them).

The second question, what assumptions and conclusions the expert has reached, is designed to elicit the background knowledge that the expert brings to bear on his problem solving. This type of question is useful in seeing how the expert is setting up the problem to solve, forming hypothesis and seeing what knowledge structures that organize the data presented.

The third question, which links the current data to previous data and conclusions, is designed to get at the integrative or truly "generative" processes that the expert uses to put together the assessment of the situation and arrive at a solution. Responses to this question give indications of what data the experts group together, what types of intermediate conclusions the expert reaches and how smaller sets of data fit into successively larger sets.

The fourth question, what further data the expert would like to have, is designed to get at the priorities the expert has in terms of information requirements as well as what hypotheses the expert is developing. A crucial follow-up question to the expert's response is why the expert wants that data.

Here, the elicitor is actively trying to see where the expert is going in his problem solving. This is an important issue since the structure of this technique forces the expert to follow a specific path of data processing (since the elicitor controls the presentation of data). It is important for the elicitor to assess what the expert would do if given the choice to pursue the problem in his own way. We justify having the elicitor control the data presentation (although clearly the technique

could be run with the expert controlling the data he receives) by noting that, in a realistic environment, very often the data will come in a seemingly random fashion as a variety of collection and analysis assets will be reporting back information as they can, even if it is not in the expert's preferred order.

After the expert has responded to these questions, the elicitor iterates to the next piece of data and the cycle repeats until the supply of data is exhausted. At the point at which the data is exhausted, the elicitor can ask the expert what additional piece of data he would most like to have. The elicitor can then make up that data, if he has the expertise to do so, have a subject matter expert consultant make up the data or ask the expert himself to make up the data and proceed with it. This latter method will allow the expert to develop his hypotheses better, which may have the advantage of seeing how that is done and have the disadvantage that it may not challenge the expert to develop competing hypotheses (unless the elicitor instructs the expert to do so).

Unstructured interview. As the expert is progressing through the problem solving technique, the elicitor gradually phases in more and more interview-type questions. Here, the interviewer is trying to clarify what the expert is doing, arrive at generalizations that can be abstracted from what the expert is doing, and to force the expert to think more broadly about the problem and consider more alternatives.

In terms of clarification, the elicitor may ask the expert to summarize what he has been doing, explain the rationales behind it, and clarify things that the elicitor does not understand (presumably as problem solving is progressing, the expert is doing less of a "dump" on pieces of data and more complex reasoning, which may require clarification for the elicitor). One type of clarification that the elicitor may want pertains to the critical features behind rules and procedures that the expert is using. Hence, the expert may ask what made the expert come up with a particular conclusion.

In terms of generalization, the elicitor is trying to find out the general principles and rule that the expert is using while forming a solution to the problem. The elicitor may ask questions like "Is that a general rule?". This type of question extends the clarification-type question of finding critical features by seeing what other instances or class of instances will prompt usage of a particular rule or problem solving procedure.

The elicitor may also challenge the expert to consider alternative hypotheses or solutions. Questions like "what other conclusions could be drawn from this?" are appropriate. Often an expert will have responded to different pieces of data in ways which suggest different (or opposing) conclusions are possible. If the elicitor can catch these, he might call these apparent contradictions to the expert and ask him to resolve them. The elicitor (or the consultant) should be prepared to play "devil's advocate" in dealing with the expert. While this may be difficult at first, if more than one expert is used in the same problem, a list of these alternate hypotheses might be developed across experts. The elicitor can draw from this list to challenge subsequent experts.

5.0 GUIDELINES FOR USING KNOWLEDGE ELICITATION METHODOLOGIES AND TECHNIQUES

In Section 4, we outlined two contrasting knowledge elicitation methodologies, interpretative and generative, as well as different elicitation techniques (e.g., problem solving interview) for these methodologies. In this section, we offer guidelines to help a prospective knowledge engineer decide when to use which methodology and which techniques. Such a decision could potentially involve several considerations: characteristics of the problem area, characteristics of the expert, the eventual application to which the knowledge is to be used and the types of knowledge the elicitor is trying to obtain.

5.1 Problem Area Characteristics

Our present studies addressed the first two factors although we offer guidelines that take into account all four factors. The problem characteristics play an important role in determining which methodology and elicitation techniques to use. In the present study, two problem areas were examined: situation development and order of battle analysis. While both involve intelligence analysis, the two problem areas have important fundamental differences.

First, situation development is a high-level integration task. The situation developer must integrate diverse bodies of information that can lead to a rather open-ended set of conclusions (there are, of course, some general classes of conclusions, e.g., attack, defend, etc.). The order of battle analyst, on the other hand, operates at a much lower level of abstraction. The order of battle analyst works with a limited set of templates (e.g., motorized rifle division) to which he maps incoming data.

The difference between situation development and order of battle analyses can be characterized by several features which have more widespread generality. The first characteristic is the level of generality that the problem area will deal with. As noted above, situation development deals with information at a much more general level than does order of battle analysis. As a result, we argue that situation development is more conducive to interview techniques than order of battle analysis since, as argued in Section 4, interview techniques are good at eliciting more general knowledge. Because order of battle analysis primarily deals with a more data-oriented level of abstraction, we argue that it is more suitable for a problem solving technique than situation development. As argued in Section 4, problem solving techniques are best suited for eliciting more specific or data-oriented knowledge.

Another critical feature which distinguishes situation development from order of battle analysis is the pool of solutions that could possibly arise out of the analysis. As argued above, the situation developer has a wide range of solutions he can come to (i.e., the enemy can have numerous possible courses of action open to him) whereas the order of battle analyst is working with a more limited set (i.e., there are only so many types of units a given enemy has). Having a large set of potential

solutions, particularly when many of them might be novel, requires the expert to engage in a more generative type of problem solving (i.e., the expert must "generate" the solution). This suggests that a form of the generative methodology might be most suitable. This implies that for situation development experts, the generative method might be most suitable. In particular, a variant of the data-driven problem solving approach may be helpful where the data presented are at a higher level of generality (e.g., a developed terrain analysis, a complete OB, etc.).

When the potential solution set is small and well-known and the problem is largely deciding which solution is appropriate, problem solving will largely be driven by the pre-existing solution set or be "top-down" in nature. This is descriptive of the essence of order of battle analysis. Hence, the interpretative method might be most appropriate for order of battle analysts. In particular, the structured interview technique may be particularly useful in eliciting the OB analyst's general problem solving approach, while the top down problem solving technique may be useful in eliciting the frames or templates the expert has plus the inference rules for building them from raw data.

Another key feature which characterizes a problem solving domain (and was alluded to in, and relates to, the number of potential solutions that could arise) is the degree of novelty associated with potential events and outcomes. In general, novelty requires the expert to act in a generative mode, constructing new knowledge structures and new solutions. Such a domain feature would suggest that a generative elicitation methodology, particularly one which emphasizes data drive problem solving might be most appropriate. In such instances, the problem should be adapted to include new problems or new data configurations.

Yet another key feature of domain is the degree of uncertainty associated with the domain. We argue that resolving uncertainty requires the execution of specific procedures and evaluations of conclusions they lead to. Kahneman and Tversky (Kahneman, Slovic and Tversky, 1982) argue that people will often use conceptual (or mental) models to reason about uncertainty. Hence, our notion of mental models, coupled with inference rules, may play a critical role in reasoning about uncertainty. We suggest that problem solving techniques are most useful at eliciting these mental models and inference rules.

One feature that characterizes domains is whether the tasks the experts perform involve synthesis of bits of data (analogous to situation development) or pattern matching (e.g., order of battle analysis). This feature may be correlated with the number of potential solutions possible (since the presence of possible solutions typically entails an emphasis on synthesis while the presence of few potential solutions allows for greater pattern matching). These tasks involve generative and interpretative problem solving, respectively. As such we would argue that data-driven problem solving and top-down problem solving, respectively, would be appropriate knowledge elicitation techniques.

5.2 Characteristics of the Expert

Characteristics of the expert from whom knowledge is being elicited are also an important consideration in deciding which knowledge elicitation techniques and methodology to use. Typically, experts with certain characteristics will be selected for particular problem areas. Therefore, it is expected that correlation between types of expert characteristics and domain features will exist. However, within a given problem area, there are bound to be differences across experts, some of which are intrinsic to the expert himself and some which are acquired as a result of experience.

5.2.1 Intrinsic qualities of the expert. Perhaps the most important quality an expert can possess (in addition to his expertise!) is the ability to articulate his expertise. Indeed, the interview techniques depend entirely on this ability. If experts are articulate, then interview techniques are appropriate and useful. Also, think aloud problem solving will be valuable. If an expert is not articulate, the elicitor will have to take more indirect approaches to knowledge elicitation: such as utilizing problems where output can be observed and measured, and applying the more experimental techniques such as recall/reconstruction, multidimensional scaling and similarity judgments, and cloze experiments.

Another dimension which characterizes experts is their cognitive style. Some experts are more intuitive while others are more analytical. Analytical experts may follow procedures more explicitly and utilize data more. As such, the generative method may be more appropriate for analytically inclined experts and in particular, the data-driven problem solving technique. For intuitive experts, the interpretative method may be more appropriate since it allows the intuitive expert to deal with generalities and not get caught up in the nitty-gritty of data. Intuitive experts may be good at analogical reasoning and therefore may be particularly good at high-level similarity judgments as well as recalling similar episodes from memory that share common high-level themes.

5.2.2 Experimental differences across experts. There are two broad categories that may fall under the heading of experimental differences across experts. These differences acquired from training (including real-world experiences) and differences as a result of an assigned organizational role. With regard to training, two broad types of training occur. The first is a classroom and book training which typically features doctrinal approaches to problem solving and a general discussion of underlying principles. The second type of training features actual experience (typically in real world contexts, although in the military arena this is relatively rare with realistic problems.

Classroom or book knowledge is typically conveyed through verbal media (either lectures or books). Examples tend to be more general in nature, hence the resulting knowledge representations will tend to be rather abstract. As a result of these two factors, we argue that interview techniques are appropriate for eliciting "book" knowledge. Experimental knowledge is derived from doing and hence may be more procedural and less language-oriented than book knowledge. An expert may

not be as easily able to articulate such knowledge. Hence, problem solving techniques, particularly those rich details, may be most useful in eliciting knowledge derived from experience. In addition, techniques such as critical incidents which require experts to draw on experiences would also be useful.

With regard to organizational role differences between experts, there are a number of distinguishing factors. The first factor relates to the above distinction between "book" learning and experimental learning, and that distinction is whether the expert is a teacher or a doer (realizing of course, that many experts are, or have been, both). Teaching is the mirror image of the classroom student. Here, the teacher must be able to articulate knowledge and understand general principles. Hence, the interview techniques may be especially useful. The doer is similar to the student involved with experimentially-based training. The doer focuses on practical applications which require a more detailed orientation to knowledge, as well as knowing the procedures and their nuances for specific situations. Therefore, a problem solving approach would perhaps be most suitable for knowledge elicitation for "doers." Again, techniques such as critical incidents, which are designed to capture knowledge relating to experiences would also be suitable.

Another factor which distinguishes different experts is their position within the organizational hierarchy. This is particularly true in the military setting where a formal ranking system is established. Typically within hierarchical organizations, those with lower tanks focus more on circumscribed tasks which are detail oriented. Higher ranking personnel deal more with the "big picture," deal more with generalities and conclusions, and tend to integrate output from the lower levels. This would suggest, broadly, that the interpretative method might be more suitable for higher ranking experts while the generative method might be more suitable for lower ranking experts. There is an important qualification to this. The data driven problem solving technique, which is part of the generative method, is good at capturing the integrative function. A modification of this technique, using high level inputs, might be appropriate for high level experts. The decision as to whether or not to include this technique might be driven by considerations as to whether the high level expert has a well formed script (such as METT-T) to perform the integrative function or whether the integration has to be performed in a "generative" fashion, i.e., without a predetermined plan for integrating.

5.3 The Application Area That the Elicited Knowledge is to Serve

One consideration which may guide knowledge elicitation is how the elicited knowledge will be put to use. We identify three applications which could benefit from knowledge elicitation and building models of expert knowledge. These are building expert systems, training, and identification of experts and task requirements.

5.3.1 Expert systems. Knowledge elicitation can benefit the design and construction of expert systems by providing the knowledge base the systems used and the algorithms for acting on that knowledge base and producing solutions to problems. Two things characterize expert systems:

the need for explicit procedures and the need for concrete output. Hence, problem solving techniques are probably the most important elicitation technique to use.

We have discussed two techniques which utilize problem solving: top-down problem solving and data-driven problem solving. Each of these techniques can serve a useful role in expert system design. Top-down problem solving can be useful in eliciting the general problem solving process and steps that experts go through. Data driven problem solving can be useful at eliciting the situation-specific variations in the general process, as well as how experts respond to specific pieces or groups of data.

5.3.2 Training. Training differs from expert system design in that the emphasis in training is typically on problem solving processes rather than output. There is stronger emphasis on the rationales that students have compared to say, what answer they come up with (especially in military examples where there may not always be a "right" answer). Training typically involves teaching general principles, problem solving procedures, and allowing students to pick up the details through experience. Hence, the interpretative elicitation method may be more suitable in eliciting how experts generally solve problems, which in turn could serve as the model for teaching students.

However, as argued, the emphasis is also on the rationale underlying the problem solving process as well as the process itself. As we have argued, these rationales can be represented by mental models. So the elicitor must tailor his elicitation techniques to get at these models. Techniques which may be helpful in doing this include interviews, critical incidents, and those which employ analogical reasoning such as sorting experiments.

5.3.3 Identification of experts. Often it is necessary to identify experts or expert requirements for particular jobs, like consultation, etc. Here the interest is in identifying what capabilities prospective experts have and mapping them to the requirements of the job (or whatever else the expertise requires). While expertise is domain specific, and the types of knowledge that experts have will vary from domain to domain, nevertheless there are still general differences between the way experts solve problems and the way novices solve them. Hence, regardless of the domain, we would expect experts to exhibit a number of traits.

First, experts will have a great deal of factual knowledge about their domain. Such knowledge might be captured in frames, semantic nets and production rules. A good technique for eliciting this type of knowledge is the data-driven problem solving technique supplemented by questions designed to flesh out the details of the knowledge being elicited (e.g., what are the components of a motorize rifle division?). These questions should be generated using the structured interview technique which is designed to flesh out the different slots or context components of knowledge being elicited.

A second feature that characterizes expertise is that experts have an in-depth causal understanding of how events are produced in their domain

of expertise and the underlying rationale behind their problem solving procedures and how those procedures relate to the events being produced. Cloze experiments are useful in eliciting the knowledge underlying how events are produced. A variation of cloze experiments, where the unfilled slot or event is a future one, is useful at eliciting knowledge regarding how plans will influence future events.

A third feature that characterizes expertise is that experts have a lot of high-level planning strategies and heuristics which allow them to set up problem solving, and generate plans and solutions. This high-level knowledge is best elicited by the interpretative elicitation methodology, particularly by using top-down problem solving over a wide range of problems. The elicitor can take this one step further to understand what criteria experts use to choose among high-level planning strategies and mapping them to specific problems by conducting sorting and similarity judgment experiments using the different problems and solutions of the top-down problem solving technique.

A fourth feature that characterizes expertise is that experts have well-integrated knowledge that links high-level knowledge to low-level knowledge. One method of testing for this would be to apply both the interpretative and generative methodologies on the expert. Two findings should come out of this if the subject is in fact an expert. First both methods should be successful in eliciting a lot of knowledge. Second, and most important, there should be strong linkages between the knowledge driven from a bottom-up strategy and a top-down strategy (i.e., if knowledge is well integrated then using a top-down strategy should not only elicit high-level knowledge but low-level as well, and vice versa. Experts should develop a similar solution and reason using largely the same knowledge, if in fact high-level and low-level knowledge are well integrated).

5.4 Types of Knowledge

The elicitor may be interested in certain types of knowledge such as inference, decision making, planning, etc. These different types of knowledge may influence the best ways to go about eliciting them. A general rule in elicitation would be to set up the session so that the expert is performing those tasks that involve the type of knowledge the elicitor is interested in. Hence, problem solving techniques are strongly indicated.

If the desired knowledge is inference-related, the data driven technique seems most suitable. Decision making and planning may be best elicited by the top-down problem solving approach since those tasks typically occur once the inference mechanisms have been run and the context is determined. Knowledge regarding facts and data (if that is the desired knowledge) might be easily elicited from interview techniques, providing of course, sufficient indices are provided to the expert. Here, using a subject matter expert as a consultant may be useful in generating such primes. Managing resources both human and others may be another type of desired knowledge. Such knowledge integrates planning, decision making

and others and is generally a very high level task. As such, the interpretative methodology might be the most suitable for knowledge elicitation.

5.5 General Considerations

There are a number of general issues to consider in knowledge elicitation other than what methodology or techniques should be used for what domain or what expert. These include issues like how many experts should be used and who they should be, how long should the elicitation sessions be, and how to evaluate the success of knowledge elicitation as it is ongoing, including the questions of whether and when to change strategy.

5.5.1 Finding the right (number of) experts. Just as mining for gold depends more on whether or not there is gold (than on what tool the miner brings) eliciting expert knowledge is only as successful as the availability of expert knowledge to elicit. Unfortunately, not all domains have recognized experts or clear cut standards to measure expertise (as does chess or baseball). The military domain is even further hindered since expertise is being developed under peacetime conditions which will be dramatically different from wartime conditions.

Still there are three criteria that can be used to select experts from the pool of people who do the job and possess knowledge the elicitor needs. First, the rank of the candidate expert gives an indication of the military community's opinion of the candidate's expertise. Second, years of experience, particularly those relating to the actual domain of interest. Certain experiences like practical training, such as exercises and assignments to locations to perform domain-relevant duties (e.g., sent on a contingency mission to South America), provide important indicators of relative expertise. Finally, peer nomination can be used, where knowledgeable people in the domain field choose the people whom they believe to be the most expert. If feasible, a fourth criterion could be used, i.e., using knowledge elicitation techniques to screen experts as described earlier.

Once a pool of experts has been identified and made available, the elicitor must decide how many to use. The elicitor may have to trade-off time constraints (both his own and availability of the expert's time) against the desire to be as complete as possible. Using multiple experts can have two benefits: first, to supplement each other's knowledge and second, to corroborate each other's knowledge.

Ideally, the use of multiple experts would primarily be to corroborate knowledge rather than to supplement it. This is so because using several experts to build a single knowledge representation runs the risk of developing an aggregated knowledge structure which perverts the interconnections between the separate pieces of knowledge (i.e., different experts may interconnect knowledge differently, hence to "mix and match" across experts may lead to an erroneously connected knowledge model). However, practically speaking, it is typically impossible to elicit a complete knowledge base from a singe expert. In such cases, it is

probably most desirable to elicit knowledge base segments in depth from single experts and piece these together. For example, in eliciting knowledge regarding situation development, it may be useful to elicit knowledge regarding terrain analysis from one expert, order of battle from another, etc.

It is desirable to replicate the elicitation process over a sample of experts. The number of replications depends upon the degree of consensus the experts provide. If two experts show nearly identical responses, then this may suffice. If the experts are markedly different, then a larger sample may be required (much the same way any experimental design is generated--the size of the sample required depends upon subject variability). Additional experts serve not only to get a measure of "central tendency" of experts but also to explain why the differences exist (i.e., are there acceptable variations in the process?).

5.5.2 Length of elicitation sessions. Scheduling sessions for elicitation may be determined more by availability of the experts' time than anything else. However, if the elicitor has some flexibility, then we offer some guidelines. In general, the elicitor must trade off the need to give the expert sufficient time to get "into" the elicitation and meet technique requirements, against the desire to avoid fatiguing the expert and the desire to obtain feedback between elicitation sessions to use in guiding further sessions.

The amount of time required for techniques will depend upon the technique itself. In general, experimental techniques require the least amount of time (e.g., cloze experiments, sorting experiments, etc.) An hour or two per technique will typically suffice. Problem solving techniques may be the longest in that they require gaining familiarity with the problem, sifting through data, etc. Fortunately, problems are usually set up beforehand and the elicitor may not need to benefit much from between-session analysis to guide future sessions. The exceptions to this include cases where the elicitor may wish to chose between patterns of data he will present to the expert, or generate questions about hypotheses the expert has been developing.

Interview techniques are the most flexible in that, theoretically, interviews can last anywhere from a few seconds to years. Since interview techniques depend heavily on follow-up questions and developing trains of thought, these would benefit most by being able to break between sessions. These breaks can be used to evaluate what has been said and to decide where to proceed.

Based on this discussion, we offer the following general guidelines: problem solving techniques should be done within a single continuous session (see exceptions noted above), so that the problem stays fresh in the expert's mind. Future problem solving sessions can be devoted to giving the expert variations on the problem to develop generalizations and situation-specific variations of the problem solving process. Interview techniques should be spaced over several sessions to give the elicitor a chance to analyze what has transpired and develop follow-up lines of questioning to use. These sessions should be shorter, the length of time depending upon the interval in between sessions (i.e., the longer the

interval the more time the elicitor has to analyze the previous material). However, if possible, it is desirable to conduct daily elicitation sessions so that the materials stay fresh in the expert's mind. Therefore, the optimal daily time for interview techniques may be on the order of two hours.

5.5.3 Ongoing evaluations of the knowledge elicitation process. This is a very important but very difficult task for the elicitor to perform. While we have offered guidelines on which techniques and methodologies to use on whom, this does not guarantee a successful knowledge elicitation plan. The elicitor may have to evaluate his strategy "on-line" and make decisions as to whether changes need to be made. Such changes may be relatively minor such as rephrasing questions, or may be drastic if it seems to be the case that the whole strategy is not working.

The elicitor has three potential sources of feedback regarding the success of the knowledge elicitation strategy: his own perceptions, feedback from the expert, and feedback from the subject matter expert consultant (if one is being used). From the elicitor's perspective, he must decide whether the expert is giving him the desired knowledge (or at least whether *it seems* like the expert is giving the desired knowledge). If the expert seems to be responding to the elicitor's probes or is giving the class of answers that the elicitor's techniques indicate (e.g., similarity judgments, inferences, etc.), then the elicitation is probably going well. However, if the expert has trouble coming up with these responses, it could suggest three things, the expert is having trouble understanding the elicitor, the wrong techniques are being used to capture what the expert knows, or the expert may really not have the appropriate knowledge and the elicitation may need to be abandoned.

The expert himself may be able to distinguish among these possibilities. In our experience, experts will often openly tell an elicitor when he doesn't possess the knowledge the elicitor is trying to obtain. Also, a consultant may offer an opinion on the matter as well. In general though, the elicitor should follow a four step process for altering the elicitation process.

The first step is rephrase the questions to clarify them for the expert. This may include giving concrete examples (e.g., instead of asking "What is a motorized rifle division made up of?", the question would be rephrased, "Are there any armored units in a motorized rifle division?"). Another approach would be to tell the expert about a previous expert's response to the same question (or a doctrinal one--a consultant may help generate this) and allow the expert to agree, disagree, or comment on the response. The elicitor tries to find a format that the expert is comfortable with and adopts the strategy of phrasing questions in that way.

If the elicitor cannot find a way to phrase questions that the expert is comfortable with, the elicitor may need to switch techniques with the expert. Using our guidelines or direct feedback from the expert may given an indication as to what techniques might be useful (for this reason the elicitor should have the capability to do more than one technique with

each expert). If the new technique does not seem to work, the elicitor should switch back to the tactic of rephrasing questions before switching techniques again. Of course, if this cycle gets repeated too often, the elicitor should proceed to his next line of recourse.

If the elicitor is having trouble finding a technique that the expert can respond to, it may suggest that the expert does not have the appropriate expertise for the elicitor's purpose. If this is the case, the elicitor may wish to change strategies and ask the expert to speak about his area of expertise. Here the elicitor can ask the expert what he would feel comfortable talking about and engage the expert in a structured interview (which requires little preparation and can be done with little or no expertise on the elicitor's part).

If the elicitor finds that the expert's area of expertise is not relevant to the domain he is targeting (the consultant may give input to this), then the elicitor may decide to end the session completely.

6.0 EXPERIMENTAL/RESEARCH METHOD

6.1 Preliminary Research and Pilot Studies.

It was hypothesized that the methods of elicitation likely to be most effective in capturing expert problem solving knowledge are ones that are compatible with the way the domain expert's knowledge is structured which is, in turn, influenced by the characteristics of his problem domain. In order to develop methods of knowledge elicitation compatible with our target domain, some of our early efforts focused on learning more about the military intelligence domain that would serve as our research testbed. To accomplish this, a series of pilot elicitation studies were conducted in the context of the selected problem domain of tactical intelligence. These efforts were largely open-ended and exploratory, for the purpose of better understanding the characteristics and constraints presented by this problem domain, that would have to be factored into the design of alternative methods of elicitation that we would later implement and study at greater length.

One of the pilot efforts involved a rather brief and preliminary elicitation case study in which a consultant from Burdeshaw Associates Ltd. (BAL) participated as the expert and several members of the technical staff of DSC and some of our consultants from Smart Systems Technology (SST) jointly participated as elicitors. Some preliminary investigations of elicitation methods in the domain of combat intelligence was also conducted at Fort Leavenworth, Kansas and at Fort Huachuca, Arizona.

6.1.1 Pilot elicitation session at DSC. A principal objective of the pilot elicitation session conducted at DSC was to exercise and rehearse the kind of elicitation material that might be used in later investigations, by thinking (and working) through a concrete example. This would not only help "shake down" our initial ideas for prospective alternative methodologies, but would serve as something of an introduction to the Army intelligence domain. A range of possible elicitation perspectives were considered, varying in terms of the kind of knowledge tapped (e.g., elicitation of decision making processes vs. elicitation of subjective assessment processes vs. elicitation of standard information about objects of the domain), the source or basis of expertise (e.g., learning from sourcebooks vs. first-hand experience), and the types of elicitation (e.g., structured interview vs. protocol analysis). These alternative perspectives also reflected a range of potential research foci.

Although a range of possible case settings was also considered, the case materials that were ultimately used were those already on hand at DSC, originally developed for research done at Fort Leavenworth on decision making under "time stress" in another ARI-sponsored Army project. The case concerned a fairly standard NATO scenario in which The Warsaw Pact has invaded West Germany. ..nis Whitehead (MG, retired), our consultant from BAL, played the role of "expert"; in this case, an experienced G2 working at the division level.

In the first phase of this pilot elicitation session, General Whitehead was asked to address his remarks to a "novice" G2 who is preparing to take up the post of divisional G2 in the context of the scenario. He was further asked that the knowledge that he would impart should be limited to that which is not available in existing publications, nor routinely learned in junior level officer training courses. This could include guidance that is scenario specific, knowledge that is too new or controversial to be embodied in existing documents, and knowledge that is organizationally sensitive or goes beyond general doctrine. The session was further focused on intelligence collection management within the G2 staff, and on knowledge that can be used to guide actions in this area (as contrasted with description or causal generalization).

The pilot elicitation session with General Whitehead was divided into three segments. In the first part of the session, General Whitehead was given the background to the problem scenario and asked to respond at a rather broad level, with *general* wisdom for the performance of data collection. In the second part of the pilot session, our expert was asked to respond to *specific* pieces of information provided in the unfolding problem scenario. In the third segment of this pilot study, a top-down interview format was adopted.

Pilot Study Findings. This pilot effort was analyzed by DSC from two different perspectives. An examination from a decision analytic perspective, by Dr. Rex Brown of DSC, is presented in Appendix A, along with detailed records of this pilot session and commentary contributed by some other participants. Observations from a cognitive processes perspective with implications for our subsequent elicitation methodology are presented below.

In the first part of the session when our expert was asked to provide very general guidance for intelligence collection, it was found that while he was able to generate a few broad guidelines in response to this request, he relied extensively on the use of specific features of the scenario to cue his generalized advice. After providing some broad and rather abstract form of guidance, he would typically elaborate on and explain the generalization in terms of specific examples. It appeared that his lower level or generative knowledge was very well integrated with (i.e., closely connected to corresponding) higher level or interpretative knowledge. Moreover, since he was less experienced as a lecturer than as an implementer of these general principles, it was difficult for him to access all the relevant abstract and general concepts without frequent reference to the more concrete objects and operable processes to which they are tied, and with which they would be used in actual problem solving. Thus, the specific problem materials appeared to provide a useful vehicle for retrieval from memory, as well as for an explanation of the higher level knowledge that was sought in this part of our pilot session.

In the second part of the pilot session, our expert was asked to use the specific case problem and "play" out the scenario, both making decisions based on the information available and imagining events unfolding. By asking our expert to make inferences and take actions based on the scenario, we expected to elicit specific rules of inference and

action. On the other hand, by asking him to extend and elaborate on the scenario we provided, we hoped to elicit the higher level knowledge that provides the basis for expectations and assumptions. While some concrete facts and rules were obtained in this format for elicitation from General Whitehead, most of his remarks addressed the general goals of the problem solving and corresponding specific goals for this problem, and his remarks generalized to more specific intelligence collection strategies. One of the DSC technical staff who had used the same problem scenario with Lieutenant Colonels at Fort Leavenworth commented that General Whitehead's approach was very different from that of the Leavenworth people: the Leavenworth subjects focused almost exclusively on the "micro details" of the problem while General Whitehead appeared to focus on general strategic issues. This difference in approach supported the notion that despite the intention of the elicitor to tap specific and concrete versus general and abstract knowledge with a particular method of elicitation, a subject's responses may be greatly influenced a priori by the level of abstraction at which he is accustomed to working the problem. If this is the case, one would expect to find that higher level officers who occupy the command or "top management" positions within a given functional area will respond to most methods of elicitation with knowledge cast in more general and abstract terms (or closely linked to knowledge of this form) while individuals who work at more detailed levels of that function will respond to elicitation with problem-solving knowledge that is largely procedural and driven by specific and concrete information.

The third part of this pilot session followed an interactive interview format. A different member of the team took the role of elicitor and began to ask General Whitehead to describe *why* he would recommend or follow the intelligence collection strategies he described earlier. This prompted General Whitehead to draw a more direct link between his overall problem goals and these broad strategies and how the broad strategies translated into more specific problem solving plans (i.e., by the nature of the objects involved). The elicitor asked for elaboration on these responses and our expert provided object and process descriptions. In subsequent questions in which the elicitor would ask for rather general information (e.g., what are the greatest threats to you; tell us more about factors contributing to the success of the attack...), our expert would respond first with a description of specific examples, generally taken from the context of the case problem, and would then abstract the general principles. This interactive approach to elicitation of higher level knowledge appeared to be fairly effective. However, it was also noted that if the elicitor is trying to get at a particular level of abstraction, and it is not a level which is readily accessed by direct questions (or not in a form that corresponds to the expert's internal representation) in an interview, the elicitor will have to be persistent in asking for that information. The elicitor may need to rephrase the question in different ways to provide alternative means of cueing the retrieval or reconstruction of the desired information, and/or allow the expert time to transform information from the problem level at which he is more aware of this processing to the level of interest to the elicitor, at which the expert may normally be less conscious of his problem solving.

6.1.2 Pilot elicitation studies at Fort Huachuca. In addition to the elicitation session just described, pilot elicitation studies were

conducted at Fort Huachuca and Fort Leavenworth. This effort involved two members of DSC's project team and a consultant from BAL who served as an informal liaison as well as guide and interpreter of the military intelligence domain.

At Fort Huachuca, two pilot elicitation sessions were run and different elicitation strategies were tested in each. In one study, a member of the DSC project team conducted an interview with a Lieutenant Colonel specializing in Army intelligence. The interview focused on intelligence gathering, but the interview format was open-ended and unstructured in order to study the effectiveness of this approach to elicitation. It was found that although this method yielded some data that could be encoded into interpretative or generative knowledge components, the interview was generally too undirected to provide enough information to yield a complete representation of either the interpretative or generative knowledge that was partially tapped. From the experience of this session, it was concluded that the elicitor must play a more active role in directing the discussion and that his questioning should be done with the objective of obtaining more complete representation; in particular, one that includes a more thorough description and explanation of the problem concepts and actions being discussed.

A second pilot study at Fort Huachuca concerned knowledge elicitation sessions in which the intelligence experts (a retired division G-2 and a retired corps G-2) worked through a standard Fulda Gap training scenario. Each subject was asked to play the intelligence staff role that they were most experienced with, and to describe the intelligence information they felt would be necessary to have in order to do their job. The session was conducted with relatively little interference on the part of the knowledge elicitors, who generally restricted themselves to questions to clarify the statements made by the experts. The problem they were given was such that the experts were able to simulate (describe) the intelligence gathering process as well as the information they would typically receive as a result of that process. This approach to elicitation was found to provide both a greater depth of information (in the context of the specific problem) and a wider range of problem-relevant information than what was obtained in the open-ended interview. The latter finding may have been the result of providing, through the use of the specific problem, a much greater and more varied set of cues for retrieval and reconstruction of relevant knowledge from the expert's memory. More generally, these results suggest that when working on specific problems, the expert may call in a wider range of knowledge structures than when he attempts to describe or discuss his problem area without a particular focus or well-defined scope. An implication of this finding, regarding the use of specific problem solving for elicitation, is that the knowledge elicitor may wish to define his problem scope more narrowly until he is ready to tackle the wider range and extent of the knowledge sources and structures that may be evoked.

6.1.3 Pilot elicitation studies at Fort Leavenworth. At Fort Leavenworth, we investigated the usefulness of observing group decision making as an elicitation technique. This evaluation was based on two

group decision making exercises observed at the Command and General Staff College (CGSC).

The decision making took place in a classroom exercise in which the instructor played the role of division commander and the students, divided into two groups, each assumed the role of some member of the commander's G2 or G3 staff. The students were briefed on the division's mission and the status of the battlefield at the point when they took up their position on the staff. The maps displayed on the walls reflected the battle scenario's current status. A computer terminal in the classroom then printed out a series of brief messages similar to the kind of reports that a division commander's staff might receive in the course of tactical battlefield operations. The sequence of messages included MOVREPs, SPOTREPs, SITREPs, weather reports, AIR DEFWARNs, friendly equipment status, friendly personnel status and other reports concerning enemy locations and actions. From this stream of data the student/staff members pieced together a picture of the battlefield and recommended friendly courses of action. The instructor/division commander would periodically intervene to critique the estimates and plans that were being developed.

In this group exercise three sources of data were available: direct observation of the actions of the participants, listening to the discussions they had between them and copies of the briefings they gave the instructor of the class. Unfortunately, there was very little opportunity to direct questions at the participants, either to clarify what they were doing or to attempt to build knowledge representations of what they were doing.

As a result, our overall evaluation of using this kind of exercise as a knowledge elicitation technique as an initial method for an elicitor unfamiliar with the problem domain, or as the sole method on which knowledge representations would be built, was rather negative. Two major problems with this approach were: (1) trying to infer how the participants were arriving at their decisions and (2) trying to keep track of each participant's input into the problem-solving process, since there was a great deal of interaction among the individual participants, who were typically playing more than one role in this staff exercise. Having a domain expert present to explain the decision making process was very helpful. He was only able to explain what was going on at a rather general level, however, since it was difficult to keep up with the numerous and fairly complex interactions that were going on in parallel. If it were a matter of having our expert consultant track and explain the observed behavior of an individual domain problem-solver, this technique may have been far more effective as an elicitation approach to be used rather early on in building a domain knowledge base.

Since the knowledge of any individual member of a division G-2 staff must include a thorough understanding of how his problem-solving interfaces with that of others in the G2 and G3 functions, observation of problem-solving in this realistic group setting would be needed at some stage, however. This could take place perhaps after elicitation of the autonomous problem-solving knowledge is largely complete and the elicitor is better versed in the domain. At that point, observation of the group decision-making process should enable the elicitor to capture the

knowledge of how and when interaction with other specialized areas or experts should occur in a given subdomain's problem-solving.

6.1.4 Implications of the pilot studies for subsequent research. The pilot studies provided evidence of the extensive use of both interpretative knowledge (e.g., rather abstract goals and plans) and generative knowledge (e.g., concrete data driven actions and inferences) in problem-solving in the tactical intelligence domain. Different forms of knowledge also appeared to be used at different levels of abstraction (e.g., object versus process knowledge). This observation supports the hypothesized need to develop knowledge representations to capture *both* higher levels and lower levels of abstraction and corresponding methods of elicitation for acquisition of tactical intelligence expertise.

The elicitation experiences of the pilot studies further indicated that highly unstructured and open-ended elicitation techniques would not be as effective with most experts in tactical intelligence as more directed methods would be, even in acquisition of high level, interpretative knowledge. This appears to be due, at least in part, to the manner in which these experts normally function in their domain. Higher level goals such as supporting the commander's accomplishment of his mission remain fairly constant across problems, while the actual use of intelligence collection and analysis strategies, and sequences of actions to handle a particular problem situation, depend very much on the specifics of a tactical situation. Moreover, since most of these experts are not typically called upon to explain or teach their job to absolute novices, they don't have a fairly complete and coherent presentation of problem-solving in their specialty prepared for the asking as might be the case with experts who also function as lecturers and instructors in their specialty.

It also appeared that, based on the Fort Leavenworth pilot study, "naturalistic" observation might not be a suitable method, at least at the initial phases of knowledge elicitation. Although the experts are engaged in solving a specific problem and the format is highly structured from their perspective, mission intelligence experts realistically work as part of a group of interacting problem solvers operating roughly in parallel. This situation is generally too complex and unbounded for an observer who is not very familiar with the domain to make effective use in knowledge elicitation.

For the initial phases of elicitation, and in our preliminary research on methods, it appeared to be wise to restrict ourselves to methods in which only one expert's knowledge was being elicited at any one time, and methods that provided varying degrees of structure and direction for the discussions with experts.

Our pilot studies also emphasized the value of having someone on the elicitation team with domain familiarity present at the elicitation sessions, to clarify and explain to us what the military personnel were doing and saying, and similarly translate for them what we wanted to do or needed to know. The effectiveness of the elicitation efforts appeared to be so much enhanced by this that we planned to have a team member with

military experience accompany us in all our subsequent elicitation sessions with military intelligence experts.

Subsequent to the theoretical work on development of integrated representations of interpretative versus generative knowledge, and of some rather general elicitation strategies to capture either interpretative or generative knowledge, the focus of the project shifted to preparation for our elicitation field studies. This involved the development of experimental methods and materials that would satisfy our research goals as well as the practical constraints imposed by the military environment in which our studies would be conducted.

This section of the report describes the subdomains of tactical intelligence to which our elicitation methods would be applied, the environment in which elicitations were conducted, and the consequent design of experimental materials to accommodate the characteristics of this particular research "testbed" while meeting our theory-based research objectives. The procedures actually used in interpretative versus generative elicitations are subsequently described, followed by a log of the actual data collection. The log of elicitations includes a description of the interview sessions conducted at various Army bases including the time and location, the participants, and the method of elicitation used.

6.2 Field Unit Studies

6.2.1 Domains of expertise selected. The purpose of the field unit studies was to test the two elicitation methodologies (interpretative and generative). Two contrasting domains of expertise were picked as testbeds and the efficacy of the interpretative and generative methods were subsequently compared. In selecting the two domains, we were driven by two considerations: first, that the domains fall within the category of intelligence analysis, and second, that they represent different functions which can be characterized by different cognitive processes. The two domains chosen were situation development and order of battle analysis.

Order of battle analysts produce an assessment of the identification, strength, command structure, and disposition of personnel, units and equipment of the enemy. They rely heavily on templates which describe the organization and composition of enemy combat forces. Hence, much of the order of battle analysis revolves around matching data to templates, which suggests an interpretative approach to problem solving.

Situation development analysts produce a broader intelligence estimate that includes the order of battle analysis, terrain and weather information, enemy doctrine, etc. These various kinds of information are combined to provide the commander with an analysis of the area of operations and enemy capabilities that can influence the friendly mission, thus providing a basis for planning friendly operations. Since the primary purpose of situation development is to infer probable enemy courses of action by aggregating bodies of data, one would expect situation development to be a largely generative process.

6.2.2 Materials. A set of materials was developed for each of the techniques used in the field studies. For the structured interview, a set of templates was developed for the difference knowledge structures. As discussed in Section 4, these templates are used to generate questions designed to fill the slots in the structure. These templates were also used in the data analysis (see Section 7); a copy of these templates are presented in Appendix B.

For the problem solving technique, a standard TRADOC teaching scenario was used. The scenario depicted a U.S. division about to conduct a passage of lines through a division in a defensive posture in order to go on the offensive against Soviet forces in West Germany. In addition to general background information, data was available in the form of a Corps periodic intelligence report (PERINTREP) and an intelligence summary (INTSUM) from the division currently on the defensive. Enemy order of battle templates were also provided. For the data-driven problem solving technique, the INTSUM and PERINTREP were cut up into individual messages and presented one at a time. A copy of the problem solving scenario is presented in Appendix C.

In addition, supplemental techniques of critical incidents and similar incidents were used. Question templates for these techniques are included in Appendix B.

6.2.3 Field units visited. In cooperation with the Army Research Institute (ARI) and the United States Army Forces Command (FORSCOM), Forts Bragg, Carson and Huachuca were selected as sites for field studies. Participating in the studies were representatives from the G-2 shops of the 82nd Airborne Division at Ft. Bragg; the 4th Infantry Division at Ft. Carson; and instructors from the U.S. Army Intelligence Center and School (USAICS) at Ft. Huachuca.

6.2.3.1 *Ft. Bragg*. Six subjects were recruited from Ft. Bragg: 3 representing order of battle analysis expertise; 3 representing situation development expertise. Subjects ranged in rank from Warrant Officer to Lieutenant Colonel. Subjects had a variety of roles within the division G-2 shop including order of battle technician, assistant G-2, and the G-2 himself. Each subject was available for one-half day for knowledge elicitation.

6.2.3.2 *Ft. Carson*. Five subjects were recruited from Ft. Bragg: 3 representing situation development expertise; 2 representing order of battle expertise. Subjects ranged in rank from Staff Sergeant to Major. Included in these were an order of battle analyst, the division OB technician, the head of the All Source Production Secion (ASPS), the head of Collection Management and Dissemination section (CM&D), and an assistant G-2. Each subject was available for a full day for knowledge elicitation.

6.2.3.3 *Ft. Huachuca*. Nine subjects were recruited from Ft. Huachuca: 5 representing order of battle expertise, 4 representing situation development expertise. Subjects ranges in rank from Sergeant to

Major. All subjects were instructors at USAICS. Subject availability ranged from 2-10 hours. Subjects were run in blocks of 2-3 hours each per day.

6.2.4 Procedures. A total of 20 subjects were used in field studies; 10 representing situation development expertise and 10 representing order of battle expertise. Within each functional speciality, half the subjects received the interpretative elicitation methodology and the other half received the generative elicitation methodology. Supplemental techniques were applied whenever time permitted at Ft. Carson and Ft. Huachuca, and typically as a supplement to the interpretative method (the generative method proved so rich that it consumed subject's available time).

Knowledge elicitation was conducted by two member teams. One team member served as the principal knowledge elicitor who asked the majority of the questions. The second team member was a subject matter expert who served as a consultant. The consultant's role was to administer the problems during the problem solving technique, answer technical questions pertaining to the subject area, and clarify misunderstandings that arose between the elicitor and the expert.

The elicitation sessions were tape recorded and the tapes were later transcribed verbatim. In addition, the elicitor took notes which were used to supplement the tapes. The transcripts and the notes were used as the source of data in the analyses reported in Sections 7 and 8.

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7.0 DATA DOCUMENTATION AND SAMPLE DATABASE

7.1 A Log of Data-Collection Interviews and Development of Knowledge Model

In this section we illustrate our elicitation methodologies by presenting excerpts of elicitation sessions we conducted. These excerpts will illustrate the different procedures we used, the questions and follow-ups that we asked and how knowledge models were generated from the subjects' responses. This section is broken down by elicitation methodology (interpretative/generative). The format of material presented is as follows. Since the application and analysis of each methodology is the same regardless of whether the situation assessment or order of battle domain is used, only traces for situation development are presented. The raw text is given. We present the text in essentially unedited fashion as it occurred in the session. We do omit tangential remarks (such as if the expert asks whether he can mark on the map). The reason behind this is that we do not wish to risk altering the expert's meaning by rewording what he says. Hence, the expert's responses may often resemble "stream of consciousness" thought. Occasionally, for the sake of readability, we include parenthetical remarks to clarify what the expert has said. However, these remarks are always enclosed in brackets so that the reader will know which they are. Beneath the text in italics are explanations as to the purpose of the questions asked. Following the text are the *representations* constructed from the text with explanations as to how the representations were constructed. Note that each paragraph in the text is numbered for purposes of reference.

7.1.1 Interpretative method.

Situation Development Expert. The following material is excerpted from an interview with a division G-2. The first part demonstrates a focused interview designed to build a script of the process of situation development. Essentially the elicitor will be going through his template of the script and try to fill in whatever slots are there. Along the way, the elicitor will ask for elaboration or clarification to fill in details. Further, the elicitor will often ask questions of the form, "Is there anything else?" in order to get as complete a response as possible.

1. Elicitor: Now, let me ask you initially, are there different kinds of situation development or conditions under which, say, the procedures might be different, say, of mid-intensity or low-intensity or high-intensity conflict, or do you basically go through the same types of procedures in all different situations? In other words, [with respect to] geographical locations or intensity of conflict, are there different kinds of procedures that you would go through in different kinds of situations or would you say that they're basically the same?

   Question is designed to get at tracks within the situation-development script, i.e., what conditions might affect how situation development is done.

2. Expert: I think there is a basic process; I think there are basic variations of the basic process with respect to conflict, and I also think that there is probably a variation of the process by echelon where the function is taking place.

3. Elicitor: OK, so we have basically two dimensions: the conflict and the echelon that you have just mentioned. Let's take them in turn now. In the conflict, could you say what the different kinds of conditions of conflict are that might determine how you might go about developing the situation?

   Elicitor takes the expert's answers and asks him to elaborate.

4. Expert: One of the things we look at frequently here is low-intensity conflict to develop the situation where your principal adversary is perhaps a third-world military force lacking sophisticated weapons, support procedures. Situation development there becomes perhaps less technical, more time- and analytical-intensive, and you pose that against a high-intensity conflict, you would expect to bring to bear more technical means and a greater effort to correlate those technical means. The analytical effort is probably as great and I think the analytical effort is probably constant throughout the spectrum of conflict, all spectrums of conflict. By echelon, the situation development of the battalion level is different in terms of methodology than it is at the division level. The battalion--once it is joined, post battle--its effort is to maintain contact with the enemy force. The [S]2 is an active player in that the [S]2 can certainly determine a great many things from force in contact--probably nothing more than force in contact, disposition, morale, in some cases intent, and the means and method of doing that probably don't vary a great deal. The battalion [S]2 might want to take prisoners--I would want to take prisoners. Hopefully, we know enough about the enemy [to] not just snatch anybody on the battlefield but to go after certain types of prisoners--squad leaders, company commanders. With any degree of sophistication and accuracy of intelligence to go after higher-level personnel, command posts, etc. at battalion, regiment at a higher level.

5. Situation development might certainly involve taking advantage of known vulnerability, if the enemy has a known weakness in command and control or in command, control, and communications. Destruction of his command post, destruction of his communications would allow us to do certain things to exploit that vulnerability; cause that situation to be developed in a method and manner of our own choosing, it is so much simpler than getting inside that commander's decision cycle, not certainly, not his ...... That is about as much as I can elaborate on differences in spectrum of conflict and echelon.

6. Elicitor: Let me go on then, in developing the situation, what are your goals or objectives? What are you trying to accomplish or learn or do? What is the purpose of doing the situation development?

Elicitor asks about goals relevant to situation development.

7. Expert: The fundamental purpose is to determine the enemy intent to get inside of the enemy commander's decision making so that I can pre-empt his plans and his intended operations--to cause an initiative to move to the United States Commander.

8. Elicitor: OK, here is where I ask you one of those clarifying questions. Why are you trying to know his intentions and plans and so forth?

The question is designed to get at underlying rationale for goals. The elicitor is probing for an underlying mental model.

9. Expert: To kill him before he can take any action that would impact on our forces.

10. Elicitor: How does knowing his intentions allow you to achieve that goal of killing the enemy before he can take action?

11. Expert: That is simply acting before he acts, striking him before he can strike, disrupting his plan, train of thought, certainly his intentions, to know what he wants to do, when he wants to do it, and we're able to pre-empt that through destruction of his force or some other means and method. That's what we want to do to achieve a successful result.
12. Elicitor: OK, I am going to try to summarize what you have just said and correct me if I am wrong. So, presumably the enemy has some intend-ed sequence that it is going to try to do; you are basically trying to learn that plan or sequence of action the enemy wants to take so that you can then intervene. Does that basically capture the process?

13. Expert: Intervene before he can put that plan or that operation in motion, before he can initiate operations.

14. Elicitor: Now, is this a kind of general principle of understanding the enemy's intention as opposed to say, only in certain conditions is this useful--that sort of universal?

Elicitor wants to determine whether the expert's answer depicts a universal principle or is it tied to some specific situation. This will play an important role as to how the knowledge is encoded and at what level of abstraction.

15. Expert: No, that is universal.

We now go through the text and illustrate how to build knowledge models from the raw material. In general, we took the knowledge structure templates for scripts, frames and mental models and tried to fill the specific slots of those structures with information obtained from the raw materials. Occasionally (particularly the case with frames) these will be information contained in the text (such as when an object is being described) for which there is no slot. For example, in describing a particular combat unit, reference might be made to that unit's typical mission. Our original version of the frame template had no slot for mission. Hence, in coding that particular piece of data, we would add a slot, "has mission," to the frame and fill in that slot with the information.

The decision of which knowledge structure to use (i.e., script, frame, mental model) was guided by two considerations: first, certain questions are asked explicitly directed toward filling slots of a particular type of structure (see annotations to the above interview material); second, material is mapped to structures according to what type of information it conveys. Events and goal-oriented procedures are mapped to scripts, object-related information is mapped to frames, and descriptions of causal mechanisms or explanations for events and procedures are mapped to mental models.

We start with paragraph 1. We see from the annotations to the elicitor's question that the elicitor was trying to get at tracks involved in the situation-development script. Thus we start with a script template. The script header is "situation development." We anticipate that the subject's response will provide information relevant to the script's track.

In paragraph 2, the expert lists two factors--type of conflict and echelon--that influence how situation development is done. Hence, we list these as separate tracks in the situation-development script with the paragraph number alongside in case we need to recheck the text later on. This is illustrated below:

Script:	Situation development
Tracks:	Type of conflict (2)
	Echelon (2)

In paragraph 3, the elicitor tries to flesh out the different kinds of conflict and echelon that might influence situation development.

In paragraph 4, the expert begins by describing the difference between low-intensity and high-intensity conflict. Each of these becomes an elaboration on the type-of-conflict track of the script, e.g.,

Type of conflict (2)
Low-intensity (4)
High-intensity (4)

In addition, the expert describes briefly how situation development differs in these two types of conflict; namely, that in low-intensity conflicts, situation development is less technical and more time- and analytical- intensive, etc. This information can be used to build the representation of the low-intensity situation-development track. Unfortunately, there is not much detail given so we would enter what is given and be on the lookout for more information later. Information that is provided is given below.

Track:	Low-intensity conflict (4)
Roles:	Adversary--third-world country (4)
Props:	Weapons (4); support procedures (4)

This information can also be used to construct a frame describing the features of the conflict itself (as opposed to the track which describes the process of situation development under those conditions). In order to construct this frame, we would take a frame template and fill in slots.

First, we label the frame-ID "low-intensity conflict--third-world country" since that describes what the expert is talking about. We then go down through the list of slots and see which can be filled from the text. The first slot is "frame-of" which is a description of what the frame is. In this case, we are talking about a battle with a third-world country. The "is-a" slot refers to the more general category of which the frame is a part. In this case, battles are a type of conflict; hence, "conflict" would go in the "is-a" slot. The expert makes no reference to what the frame is similar to; hence, that slot is left blank. For "has-parts," the expert lists weapons and support procedures that make up part of the conflict. The "part-of" slot refers to a larger unit that the current frame is part of (e.g., a battalion is part of a regiment). The expert does not give any information here, or for the next slot --"size"-- either. The next slot--"descriptions"--allows for a description of the frame. This might be a list of features which describe or characterize the frame. One example that the expert lists is that the opponent is a third-world military force. Hence, this feature would be listed under "description." The next slot--"spatial configuration"-- remains unfilled since the expert provides no information.

After this, the template contains a place to list features or attributes associated with some of the slot fillers. This is almost like a semantic net-type representation format and, in fact, would serve as a good place for frames and semantic nets to interface. In this section, we note that the expert has characterized the third world's weapons and

support procedures as being "not sophisticated." Hence, we place the following in this section: weapons - not sophisticated (4); support procedures - not sophisticated (4).

Finally, we note that the expert compared the low-intensity conflict with high-intensity conflicts. Since our template does not have slots for making comparisons or contrasts, we generate a slot of our own to capture this knowledge. Under this "compared to" slot, we would have "high-intensity conflict" (based on what the expert said) and the differences are: weapons are more technical (in high-intensity conflict) and support procedures are more correlated. A commonality is the analytical effort. As a note, this comparison between high- and low-intensity conflicts can be used to construct part of a "high-intensity" conflict frame.

We now present the "low-intensity conflict--third-world country frame."

Frame-ID:	Low-intensity conflict--third-world country (4)
Frame-of:	Battle (4)
is-a:	Conflict (4)
has-parts:	Weapons (4), support procedures (4)
Description:	Opponent: third-world military force (4)
Compared-to:	High-intensity conflict (4)
	Differences: weapons - more technical (4)
	support procedures - more correlated (4)
	Commonalities: analytical procedure (4)
Object/Features:	Weapons - not sophisticated (4)
	Support procedures - not sophisticated (4)

Having represented what the expert said about the different types of conflict, we turn to his discussion on the different types of echelon. We again return to the tracks slot of the situation-development script which is where we anticipate the expert will be providing us with information. In fact, the expert makes reference to two different echelons that influence situation development--division and battalion. Each of these then gets listed as a subtrack under the echelon track of the situation-development script.

After listing these two echelons, the expert begins describing the situation-development process at the battalion level. This would suggest creating a battalion situation-development track using a script template. What is different in this situation is that the expert is spontaneously generating this subscript (track). Hence, the slots of the template may not be filled in a neat order. Rather, the person building the representation may have to go through the text and determine what information goes in what slot.

First, however, the battalion track gets a pointer to the battalion situation-development subscript so that the user knows that there is a knowledge structure being referred to. This can be done as follows:

Script: Situation development

Tracks: Echelon (2)
Division (4)
Battalion (4)--pointer to Battalion
S.D. subscript
Conflict (2)
⋮

This having been done, we turn to the construction of the battalion situation-development subscript. We begin by giving the subscript its appropriate label. The expert then says that when the battalion is joined in battle, it maintains contact with the enemy. The rest of the discussion centers on what happens once this occurs. Hence, the coming into contact with the enemy stimulates the situation-development process at the battalion level (according to our interpretation of the text). Hence, the battalion coming into contact with the enemy appears to be the entry condition for the subscript, and hence, will be listed under "Entry Conditions" in the template. The expert next makes reference to the S-2 (the expert actually says "2", but the elicitor knew the expert meant S-2; otherwise he would have asked for a clarification), hence naming a role in the situation-development process. The S-2 is then listed under roles.

The expert then listed some of the things the S-2 is trying to do: determine force in contact, disposition, morale and intent. These are interpreted to mean goals or objectives of the situation-development process and are therefore listed under the "goals" slot.

The expert then describes the actions involved in taking prisoners. He lists different types: squad leaders and company commanders. Hence, the expert has identified new roles and they will be listed accordingly.

The very act of taking prisoners represents procedures performed as part of the situation-development process. This suggests a scene which we label "take prisoners." The expert further elaborates on how he would go about taking prisoners, namely using "intelligence to go after higher-level personnel, command posts, etc. at battalion, regiment [and] at a higher level." This piece of knowledge is represented as an action under the "take prisoners" scene.

In the next paragraph (5), the expert states that situation development involves taking advantages of weaknesses in command and control or command, control, and communications. This gets listed as another goal of the subscript.

Following this, the expert discusses how destroying enemy command posts would favor the friendly side. Normally, this type of explanatory text would suggest constructing a mental model. However, shortly down the text the elicitor discusses this in more detail; hence the construction of the mental model is deferred until then. We, therefore, present the battalion situation-development subscript as developed up to this point.

Subscript: Battalion situation development

Associated
Script: Situation development

Goals: Determine force in contact (4)
Determine enemy's disposition (4)
Determine enemy's morale (4)
Determine enemy's intent (4)
Take advantage of weaknesses in command and control or command, control and communications (5).

Entry
Conditions: Battalion comes in contact with enemy.

Rules: S-2 (4)
Prisoners (4) squad leaders, company commanders (4)

Props: (No information provided)

Scenes: Take prisoners

Actions: Use intelligence to go after higher-level personnel and command posts at battalion, regiment, and higher echelons

Continuing in the text (paragraph 6), since the expert has said that he has listed the differences in type of conflict and echelon, the elicitor leaves the "tracks" slot of the situation-development script and goes on to the "goals" slot, asking the expert what the goals are in situation development.

In paragraphs 7 and 9, the expert lists some goals which are placed in the goals slot:

Goals: Determine enemy's intent (7)
Preempt enemy commander's plans and operations (7)
Cause initiative to move to U.S. command (7)
Kill enemy before he can impact on friendly forces (9)

In paragraph 10, the elicitor asks for an explanation as to how knowing enemy intentions allows the situation developer to achieve the goal of killing the enemy. Such an explanation-oriented question is geared toward eliciting a mental model. Hence, we will primarily be using a mental model template to represent the expert's response. Hence, we will be looking for references to context, goals, forces, objects, force/object interactions and outcomes (note that we mentioned that part of this information was given in paragraph 7; hence, we will be using some of this material to supplement the material in paragraphs 11 and 13).

In looking for objects, explicit reference is made (paragraph 7) to the friendly and enemy commanders. Since the situation developer is discussing his role, he is an implied player as well. In paragraph 11, a reference is made to the enemy force; hence, that is an object as well.

At this point, a problem arises with knowledge representation in general, and what we seem to find--mental models--in particular. Each piece of knowledge is not always stated explicitly but often is left implicit. The "mental model" slot is a case in point. The expert makes reference to striking the enemy and destroying his force (paragraph 11). He does not state what will strike and destroy the enemy force. Normally we would expect the elicitor to catch this and ask a pertinent question, but in real time, the elicitor will occasionally miss things. Hence, the person building the representation may need to fill in the gap. This can be done in conjunction with a subject-matter expert who would know what the missing information would be (this would be particularly true in cases where the information is not idiosyncratic). In this case, the friendly forces would be the ones destroying the enemy forces. We would then include "(friendly forces)" (11) in the objects slot. Parentheses are used to enclose the information to indicate it was inferred rather than explicitly stated. The number in parentheses alongside it indicates the locale of the material on which the inferred information is based.

The goal of the mental model is given in paragraph 9--namely, kill enemy before he can impact on our forces. This goal is also relevant to the situation-development script and is, therefore, encoded there.

The relevant force is also not explicitly stated, but implied from the goal of destroying enemy forces. Here, the forces would be friendly combat power. This would be listed in parentheses under forces along with "(11)", indicating it was inferred from paragraph (11).

Next is the interaction of objects and forces. In paragraph 11, the expert states that the friendly forces (implied) will strike the enemy forces before they can act. This gets listed under "force/object interactions."

Next is the "outcomes" slot. In paragraph 11, the expert lists a number of outcomes that will result from the strike. These are: disruption of the enemy's plan, train of thought, intentions, destruction of the enemy force. In paragraph 9, the expert implies that another outcome would be that the enemy would not impact on friendly forces. In paragraph 7, the expert states that preemptive enemy plans would cause the initiative to move to the friendly commander. Hence, this is another outcome that gets listed.

The only slot that remains unfilled is the "context" slot. In order to get information relevant to this, the elicitor asks (paragraph 14) whether this is a universal principle or tied to specific conditions. The expert replies that it is universal (presumably universal on the battlefield, although there are undoubtedly analogies to other contexts). Hence, this is filled in the context slot of the mental model.

The only other thing to do with regard to the mental model is to give it a label or name. This is not really essential but helps reference it for purposes of discussion. We label this mental model "disrupting enemy forces."

We now present the entire mental model below:

Mental Model:	Disrupt Enemy Forces
Context:	Universal on battlefield (15)
Goal:	Kill enemy before he can take action that would impact on friendly forces (9)
Objects:	Enemy forces (7) (Friendly forces) (11) Enemy commander (7) Friendly commander (7) Friendly intelligence officer (7, 11)
Forces:	(Friendly combat power) (11)
Force/Object Interactions:	Friendly forces strike before enemy can act (11)
Outcomes:	Enemy plan disrupted (11) Enemy train of thought disrupted (11) Enemy intention disrupted (11) Enemy force destroyed (11) Enemy forces do not impact on friendly forces (11) Initiative goes to friendly commander (7)

Once the mental model is constructed, we link it to the representation that evoked it. Recall that this mental model was invoked as an explanation of why the situation developed has the goal of killing the enemy before he can take action. Hence, a pointer to this mental model is attached to this goal which is listed in the goal slot of the situation-development script. This is illustrated below:

Script: Situation development
Goals: Kill enemy before he can impact on friendly
forces--pointer to M-M disrupt enemy forces

This concludes our section on knowledge elicitation using the interpretative interview technique. We have given examples as to how scripts, mental models and object frames can be constructed from the raw material. We have so far presented a mental model and a frame in its entirety, but have given just bits and pieces of the ituation-development script we constructed. We now present the unified situation-development script that was constructed based on the text provided above:

Script: Situation development

Tracks: Echelon (2)
Battalion (4)--pointer to battalion situation-development subscript.
Division (7)

Conflict (2)
Low intensity (4)--pointer to low-intensity conflict frame.
High intensity (4)

Goals: Determine enemy's intent (7)
Preempt enemy's plans and operations (7)
Cause initiative to move to U.S. command (7)
Kill enemy before he can impact on friendly forces--pointer to M-M disrupt enemy forces

Roles: Friendly commander (7)
(situation developer)

We now turn to a demonstration of the second major elicitation technique of the interpretative method: top-down problem solving. This technique is designed to flesh out the procedures involved in the performance of the expert's job, or in terms of our framework, to elicit the procedures to fill in the script.

This technique is far less structured than the interview technique presented earlier. Experts are given a problem and are asked to work on it as they normally would while doing their job. The elicitor may ask clarifying questions, but he is not structuring the way the expert solves the problem. The elicitor is not telling the expert, e.g., "now consider the goal aspects of what you're doing." Therefore, the elicitor does not have this *a priori* expectancy as to what kinds of knowledge the expert will emit. The elicitor must infer from the content (and responses to clarifying questions) what the expert is doing and what knowledge he is using. It is useful, therefore, for the data analyst to have either sufficient knowledge of the domain to make inferences where necessary or to have a domain expert help with the analysis.

As with the interview text, we begin by presenting a trace of the problem-solving part of the session, followed by a discussion of how knowledge representations were built from the text.

1. Expert: The first thing that I would want to do as an assistant G-2 operations officer is get out of the TOC and to talk to the G-2 operations officer of the defending division. That one-on-one would give me a first-hand assessment of how they view what's going on out there. If time continues to permit me to continue to do personal contact type assessments, I would want to talk to the brigade S-2s and the brigade commanders of the units in contact. And, in that process, I would want to do some kind of limited reconnaissance.

Expert has been briefed on the background of his problem. He has been given a mission, intelligence reports, and a map with enemy order of battle posted. Expert is asked how he would proceed from there.

2. Military Consultant: [You want to get information from] units on line that [others will] pass through?

3. Expert: Yes.

4. Elicitor: What are you going to be asking them?

5. Expert: Their assessment of the unit's actions along that first defensive belt; what are they doing and how do they do it; what is their morale like? Indications if there might be some kind of logistics problems and resupply. I'll expect the first defensive belt of the 31st MRD probably be supplied better than the 46th. [Elicitor asks Expert to role play.] I would first want to look at the brigade that holds the first avenue of approach through the 31st MRD. Avenue of approach 1 though the 31st GMRD.

6. Military Consultant: I noted that he is assessing avenues of approach. He sketched them out on the map. This would be something you would do to get yourself up to speed or get the background information on the scenario.

   Elicitor number 2 (the military consultant) summarizes what the expert was doing while there was no discussion taking place and then asks the expert why he is doing it.

7. Expert: I would want to get the G-2s from the 23rd Division (on line) assessment of the situation. The 23rd [Division], in anticipation of future operations, has done an IPB and looked at axes of advance into the 31st division sector. If I know it at the time, I will try to get specific information about specific passage points that my battalions and brigades would have to come through. Their immediate concerns are going to be what's the threats and what's the resistance they will have to face as they go through those passage points and achieve initial contact with the enemy forces.

8. Military Consultant: As the G-2 of the 23rd, I would tell you that we have observed, uh, haven't sorted out what all the activity's that's going on out here is, but there's a lot of activity and we agree that it appears that they are digging in on the defense. We

think this is probably the security area and we are trying to determine where they are setting up ambushes or killing zones. We are developing that chain of events.

The military elicitor role plays the person that the expert says he would consult. A key feature of the problem-solving technique is that the expert will often want to interact with others to get vital information. It is useful, therefore, to have someone in these other roles. This could either be other experts (in which case the knowledge elicitation may focus on a group problem-solving session) or a domain consultant, as in this case, which can simulate the other roles.

9. Expert: I've got to assume that we have this mission and my division is going to go through a deliberate set planning process. That means that the G-3 and I, my G-2, and the division G-3 are going to recommend courses of action to the commander.

10. Expert: The first intelligence assessment that we have to take into account is relative strength. We have a general idea of the relative strength that is approximately 70%. The key thing we want to do is achieve surprise, achieve breakthrough at that first defensive belt. We want to do it in such a manner that will cause enough disarray in the first defensive belt to catch the supporting units that are behind that first defensive belt in a situation where they could not respond immediately, be that response movement forward or in this case, looking at what's in the rear here, probably retrograde movement to implement the defensive sector of the 46th motorized rifle division.

11. Elicitor: So you're setting up, it sounds like, the goals that you're going to try to achieve, or in other words, ...

    Elicitor tries to abstract the purpose behind what the expert is doing.

12. Expert: Recommending courses of action.

13. Elicitor: Right, but goals that you want these courses of action to satisfy.

14. Expert: Yes, now between the [G]-3 and I, what I would recommend to the [G]-3 is that we attempt to achieve the first breach through a combination of joint air attack and ground attack and then we try to achieve it on what this is the, call that avenue of approach 1. It's clear it's the best one that's there, which represents the secondary avenue of approach, probably given what our mission is it's to achieve objective 1. I'm less concerned, I would suggest to

the [G]-3 that he asks for perhaps a change in boundary between the 54th and 53rd, unless the 53rd is also going to conduct a supporting attack or they have the main attack. I think it's important that we have control of the high speed avenues of the approach. Those are just considerations for the [G]-3 what he needs to look at and there's an interaction between the [G]-2 and the [G]-3 at this point in time, kind of loses its staff parochialness or part of a specific function in as much as the [G]-2 is going to talk about things that address the [G]-3's functional area, the [G]-3 is going to talk about things that are going to address the [G]-2's functional area and there is interaction there. I would say that those traits you'll find ought to be characterizing good staff relationships between [G]-2s and [G]-3s. The current Chief of Staff of the Army once told me when I worked for him that [G]-2s and [G]-3s ought to be interchangeable. That, I think, is certainly a desirable capability.

In paragraph 1, the expert has just been given an overview of the problem (presented in Appendix C). In response to being asked how he would work on the problem, the expert gives different actions he would take: personal interactions with other units and limited reconnaissance. These general actions suggest different scenes for a situation-development script.

They belong in scripts, as opposed to frames or mental models since they describe procedures. They are scenes as opposed to actions, since they describe generalized actions for which further subactions would be required to specify how to carry these out (e.g., "doing limited reconnaissance" is not detailed enough to tell how this should be done).

The above describes rules for distinguishing scenes from actions. It is also necessary to distinguish scenes from each other (e.g., what constitutes a separate scene vs. part of the same scene). Scenes are typically characterized by their setting, the players involved, and the goals involved. Hence, although talking to division intelligence officers and brigade intelligence officers may involve similar objectives, the settings and players involved are quite different.

Hence, talking to the G-2 operations of the defending division and talking to the on-line brigade personnel would be separate scenes. It is difficult to determine from the expert's response whether talking to brigade S-2's and brigade commanders should be represented as separate scenes, since the context and goals may be the same for both. A general principle which Schank (1982) argues for is that pieces of knowledge may be stored in one common structure until enough new information comes in to differentiate those pieces of knowledge, necessitating separate structures to represent them. We will adopt this philosophy here, assuming that talking to brigade S-2s and commanders is part of a more general scene, "talking to brigade personnel" with "talking to brigade S-2s" and "talking to brigade commanders" as separate actions in that scene. If the expert elaborates on these two actions in such a way as to suggest that they are separate scenes (e.g., goals and contexts are different), then they can be re-represented as separate scenes.

To summarize then, we would take the content of paragraph 1 and create three scenes: talk to G-2 operations of the defending division, talk to on-line brigade personnel, and conduct limited reconnaissance. Under "talk to G-2 operations," we have a specific action which is "get their assessment of what's going on." Under "talk to on-line brigades," we have actions of "talk to commander," "talk to S-2s," and subactions of "get their assessments" under each. We illustrate this below:

Script: Situation development

Scene: Talk to defending division's G-2 operations (1)

Actions: Get assessments (1)

Scene: Talk to on-line brigade personnel (1)

Actions: Talk to S-2 (1)
Get assessments (1)
Talk to commander (1)
Get assessments (1)

Scene: Conduct limited reconnaissance (1)

In the process of generating scenes, the expert has named other roles that occur in the script, namely, defending division G-2 operations, brigade S-2, and the brigade commander. If these are not already listed under the scripts role slots, we would add them there.

In paragraph 4, the elicitor wants to flesh out some of the actions that might be involved when the expert is talking to other personnel. Hence, his question is directed at just that.

In paragraph 5, the expert elaborates on what he would talk to the others about. He states he would want their assessments of what the enemy units in the first defensive belt were doing and how they were doing it. He would also want to know what their morale is like and whether there are indications of logistics and supply problems.

The expert makes the comment that he would expect the first defensive belt of the 31st MRD (Motorized Rifle Division) to be better supplied than the 46th MRD. Although the reason for this is not stated in the text, the expert has received the PERINTREP (see the problem presented in Appendix C) of the 23rd Armor Division (the division that is defending) which contains the information that the 31st MRD has priority of supply. Hence, the expert is undoubtedly making the inference that the 31st MRD will be better supplied than the 46th from this piece of information.

This inference is difficult to deal with. There are a number of possible representations for this. Perhaps the simplest is using a production rule format "If unit gets priority of supplies, then it will be

better supplied than unit that does not get priority." Production rules are not formally part of an "interpretative" representation scheme, although they are certainly readily incorporable into them.

Another way to represent this would be through a "supply" script, which describes how units get supplied. The outcome of such a script would be that units have supplies. Hence, units run through this script (e.g., those that get priority of supplies) would be better supplied than units that don't get run through the script (e.g., those that do not get priority of supplies). From the information given in the text, it is impossible to tell how the expert made this inference.

If it were essential for the elicitor to focus on this particular inference, he would have asked a follow-up question to get the answer. However, the elicitor was focusing on the actions the expert would take while talking to personnel of other units. Hence, pursuing this inference may have distracted the expert. Since the expert himself did not pursue this inference, the elicitor decided not to disrupt the expert's train of thought (generally regarded as good advice while conducting knowledge elicitation). Finally, the expert mentions that he would want to look at the brigade that holds the first avenue of approach through the 31st MRD.

In paragraph 6, the military consultant observes that the expert is actually studying the map. This offers a new source of data, what the subject actually does, in addition to what he says. Here, the expert is carrying out the actions he last talked about in paragraph 5, i.e., looking at avenues of approach.

To represent the text in paragraphs 5 and 6, we note that the expert has added new actions relating to the scenes involving talking to personnel in other units and has also generated a new scene--looking at avenues of approach. We add this information to the script:

Script: Situation development

Scene: Talk to defending division's G-2 operations (1)

Actions:
- Get assessment of what enemy units in first (5) defensive belt are doing and how they are doing it (5).
- Get assessment of enemy morale (5).
- See if indications of logistics and resupply problems (5).

Scene: Talk to on-line brigade personnel (1)

Actions:
- Talk to S-2 (1)

- Talk to commander (1)
- Get assessments of what enemy units in first (5) defensive belt are doing and how they are doing it (5).

Get assessment of enemy morale (5).
See if indications of logistics and resupply problems (5).

Scene: Conduct limited reconnaissance (1)

Scene: Look at avenue of approaches through area of mission (5)

Action: Select specific area of approach (5)

Note that in the last scene (look at avenues of approach), we generalized it from the specific cases (i.e., the 31st MRD sector, first avenue of approach) to the generic case area where mission is select avenue of approach. Through familiarity with the scenario, the person building the knowledge representation knows that the expert's mission is in the section of the 31st MRD sector. We would not expect the expert to always look at that sector (e.g., if the expert were fighting in Korea instead of Germany, he would not care about the 31st MRD sector, which is in Germany). Having a domain expert as a consultant while building such representations will help check the validity of such generalizations. Ideally, however, the elicitor would ask the expert being interviewed to supply such generalizations. Unfortunately, it is impossible from a practical point of view to have the expert clarify everything he says.

In paragraph 7, the expert discusses the desire to talk to the G-2 of the division currently on-line and also what he would like to talk to him about. What is interesting here is that the expert has made another reference to talking to personnel of the on-line division (the previous reference was talking to the G-2 operations). This suggests we need to generalize these two actions into a common scene, namely "talk to on-line division personnel" (similar to "talk to on-line brigade personnel") which replaces "talk to defending division's G-2 operations." This latter scene now becomes an action sequence in the more general scene. The new scene is presented below.

Scene: Talk to on-line division personnel

Actions: Talk to G-2 operations
Get assessment of what enemy units in first defensive belt are doing and how they are doing it (5).
Get assessment of enemy morale (5).
See if indications of logistics and resupply problems (5).
Talk to G-2 (7).
See what threats and resistance own battalions and brigades will face as they pass through axes of advance into enemy territory (7).

Note that the expert has named the on-line division's G-2 as a new role. This would be added to the roles slot, if not already there.

In paragraph 8, the elicitor's military consultant role plays the G-2 that the expert wants to talk to. Since military problem solving is a group process, it adds realism and credibility to our elicitation if we can provide the additional roles while the expert works through the problem. Therefore, it is useful to have an expert consultant when utilizing this technique.

In paragraph 9, the expert appears to make reference to a new script: the division planning process. This would suggest a tentative construction of a new script although much more information is needed. An entry condition appears to be specified--having a mission. The roles of G-3, G-2, G-2 operations (the expert referring to "I"), and the commander are named. Finally, the reference to recommending courses of action to the commander suggests either a scene or an outcome depending upon whether it is a process, a result of a process, or both. More information is needed to clarify this.

Situation development is part of the overall division-planning process. Hence, this expert may be explicitly looking at his situation development "script" in the context of a much larger one. This is very noteworthy and in looking at the rest of the text we will be interested in seeing if this hypothesis proves to be correct.

In paragraphs 10-13, the expert states explicitly that he is thinking in terms of this larger script--namely, recommending courses of action and listing the objectives these courses should satisfy. Hence, we begin to construct this new script, "division planning process," from the material in paragraphs 9-13.

To reiterate from paragraph 9, we have the script header, the entry condition (having a mission), some roles (G-3, G-2, G-2 operations, commander), and the goal/action of recommending courses of action to the commander. In paragraph 10, the expert states that the first intelligence assessment he would want to take into account is relative strength of the enemy. This suggests two things. First, part of the planning procedure includes taking into account the enemy's strength. Second, since the expert discusses the enemy's strength, it can be inferred that this gets computed somewhere. The question remains whether this is done as part of the planning script or the situation-development script. The expert offers a clue here, by referring to the enemy's strength as an "intelligence assessment" (paragraph 10). This suggests that the *production* of the estimate may in some sense be part of the situation-development process, while the *use* of the estimate may involve other parts of the planning process.

Hence, we would want to update our situation-development script to include "compute relative strength of enemy" as either a scene, an action within a scene, or (as turns out to be correct) an additional script (associated with the analysis of enemy order of battle) which is one step below situation development in a script hierarchy. More information would be required to determine exactly where this would fit. Similarly, some

actions in the planning script would include the information regarding enemy strength. This would be stored with a pointer to the place in the situation-development script where this number is computed.

Unfortunately, the expert does not explicitly elaborate on how the enemy strength number is to be used. However, we can make some inferences (which domain experts could evaluate) based on the text that follows in paragraphs 10-14. In the rest of paragraph 10, the expert lists some goals he would like to achieve (surprise, breakthrough of first defensive belt causing disarray so that supporting units cannot respond). In paragraph 14, the expert outlines parts of a plan for achieving these objectives. Presumably, the strength of the enemy plays a role in how well one can achieve these goals.

Getting back to paragraph 10, in addition to listing his objectives, the expert presents a mini-scenario of a surprise breakthrough which causes disarray and prevents supporting units from responding. This suggests a mental model. Using our template, we get an inferred context of the battlefield. The objects are friendly forces (implied by expert's reference to "we"), enemy first defensive belt, and enemy supporting units. Forces include strength of enemy and strength of friendly forces (implied). The goals are to achieve surprise and achieve successful breakthrough (which includes a subgoal of having supporting units not respond). The force and object interactions include friendly force catching enemy force unprepared (implied by "surprise") and friendly force overpowering enemy force (implied by "achieve breakthrough"). Enemy *strength might* be used in computing this event. This could be computed using a formula or another mental model. We would need more information to determine this. The outcomes are breakthrough achieved, and enemy supporting units incapable of responding. We present the representation of this mental model below.

Mental Model: Surprise Breakthrough

Context: (Battlefield) (10)

Goals: Achieve surprise (10)
Achieve successful breakthrough (10)

Subgoal: Prevent enemy supporting units from assisting (10)

Objects: (Friendly forces) (10)
Enemy first defensive belt (10)
Enemy supporting units (10)

Forces: Enemy forces strength (10)
(Friendly forces strength) (10)

Force/Object Interactions: (Friendly forces catch enemy forces unprepared) (10)
(Friendly forces overpower enemy forces) (10)

Outcomes:	Friendly forces achieve breakthrough (10) Enemy supporting units incapable of responding (10)

In addition to this mental model, we have some information relevant to the division-planning script. We outline the beginnings of this script:

Script: Division planning

Goals:	Recommend courses of action to the commander (9)	
	Subgoal:	Achieve surprise (10) Achieve breakthrough (10)
Entry Conditions:	Have mission (9)	
Roles:	G-2 (9), G-3 (9), G-2 operations (9), commander (9), enemy first defensive belt (10), enemy supporting forces (10)	
Scenes/ Actions:	Assess enemy strength (10)--pointer to situation-development script, scene/action, compute enemy strength. Set objectives (10)	

Paragraph 14, in essence, contains two sections. In the first section, the expert begins to outline a plan. In the second section, he discusses the G-2 and G-3 roles. In the first part of the paragraph, the expert recommends a joint air and ground attack. He also selects a particular avenue of approach to conduct the attack on. Each of these suggests a scene, e.g., "determine composition of attacking units" and "select avenue of approach." The expert does not elaborate on the selection of the units, but does discuss selecting the avenue of approach. He selects a particular one, avenue of approach 1 (which is in the southern portion of the enemy unit he will be attacking), which he labels the best. Since it is a high-speed avenue of approach, he recommends the attack pass through there. In order to get this avenue, he must request that the G-3 ask for a change in boundary since the avenue is part of another division sector. He will do this unless the other division needs to use that avenue.

In representing all this, we have under the scene "select avenue of approach," the action, "look for high-speed avenue of approach." We would still need information to determine what makes an avenue high speed. It turns out that the avenue the expert refers to is a major highway. This could be represented in semantic net format (although such a representation is not technically "interpretative"); highway "isa" high-speed avenue of approach.

The requesting of the boundary change really is a rule as to what should be done if the avenue of approach is not part of the division's sector. This can be represented in production-rule format (again, technically not an "interpretative" method): "If desired avenue of approach is not in one's sector and is not needed by unit whose sector it is in, then ask G-3 to request a boundary change."

The expert next discusses the interaction between the G-2 and the G-3 and that they will address each other's functional area. This could be represented in one of two ways. First, it can suggest that the actions performed by the G-2 and G-3 can have either one as the actor as opposed to assigning specific tasks to each. Second, it could suggest a separate interaction scene where the G-2 and G-3 interact and exchange information relevant to the other's area. This seems to be closer to what the expert is saying. Hence, we create a new scene with G-2 and G-3 interactions where G-2 addresses G-3's functional area and G-3 addresses G-2's functional area. We add new scenes to the planning scripts and get the following.

Script: Division planning

Goals: Recommend courses of action to the commander (9)

Subgoals: Achieve surprise (10)
Achieve breakthrough (10)

Entry Conditions: Have mission (9)

Roles: G-2 (9), G-3 (9), G-2 operations (9), commander (9)
Enemy first defensive belt (10)
Enemy supporting forces (10)

Scenes: Assess enemy strength (10)--pointer to situation

Development Script: Scene/action compute enemy strength
Set objectives (10)
Select avenue of approach (10)

Actions: Look for high speed avenue of approach (14)
("isa" highway) (14)
If desired avenue of approach is not in one's sector and is not needed by unit whose sector it is in, then ask G-3 to request boundary change (14).
G-3/G-2 interaction (4)

Actions: G-3 addresses functional area of G-2 (14)
G-2 address functional area of G-3 (14)

Finally, the expert briefly describes the "interchangeability" of the G-2 and the G-3. This is really giving a description of the capabilities (or desired capabilities) of each person. Such descriptions are most suitably captured by frames. However, this information does not seem appropriate for the slots we have in the frames we have been using (e.g., "spatial configuration"). Hence, we propose to construct a "person frame" which represents information about people. We can include slots like training, experience, tasks performed, capabilities, etc. Based on the text, we have some information for these slots. We already know that the G-2 and G-3 recommend courses of action to the commander; hence, this would be a "task performed" slot member. Similarly, addressing each other's functional areas would be tasks performed by the G-2 and G-3. The interchangeability of G-2s and G-3s suggests capabilities of each to perform the other's jobs. Hence, we construct G-2 and G-3 frames as such:

Person Frame:	G-2	
	Tasks Performed:	Recommend courses of action to commander Address G-3 functional area
	Capabilities:	Can perform G-3 role
Person Frame:	G-3	
	Tasks Performed:	Recommend courses of action to commander Address G-2 functional area
	Capabilities:	Can perform G-2 role

There is one final thing to note about paragraph 14. The expert makes reference to the Chief of Staff of the Army. Note that we have not included him in any role in either of the scripts we develop. This is because the expert did not name him as a player in any process, but rather refers to a remark made by him. Hence, the knowledge that there is a Chief of Staff of the Army is ignored unless new information is added that he plays a key role in our process.

7.1.2 Generative method.

Situation Development Expert. The following material is excerpted from a generative problem-solving session with the head of a division all-source production section. The generative or data-driven problem-solving technique is designed as a method for investigating how experts arrive at a picture or solution to a problem by responding to individual pieces of data, integrating them, and drawing inferences and forming hypotheses as they proceed through the problem. This technique serves several purposes: it allows for the elicitation of detailed knowledge and situation specific procedures; it allows for the elicitation of data-driven inference rules; and it helps elicit the procedures experts use to integrate data.

The questions the elicitor asks are driven toward these goals. The elicitor will ask the expert what pieces of data mean to him in order to elicit inference rules. This will be used to construct production rules where the antecedent conditions are those the expert comes up with. The expert may ask for critical features of the expert's rules or descriptions of the concepts he is using. This will be useful in constructing semantic network-type representations. The elicitor may also ask for underlying rationales for the expert's procedures and rules so that mental models can be constructed (much the same as in the interpretative method).

As with the interpretative method, we begin by presenting excerpts from the elicitation session and then show how the material is used to build knowledge models.

1. Elicitor: We are going to be giving you information today on situational development that is not exactly like what you would normally see. Please bear with us and you do your best to develop a picture of the situation. What I am going to do is give you pieces of information, piece by piece, and start by making no assumptions about anything and then as you gather more and more information just please let us know what picture you're putting together. We are trying to understand how you are putting the picture together and with that I will give you your first piece of information which is: At 1830 a company size force reinforced with tanks conducted a limited objective attack from the northeast on the Leidenhofer Kopf, Mike Bravo 8617. Unsuccessful, the threat forces withdrew to hasty defenses vicinity, Mike Bravo 888168 and 878180. OK, here's the report. Please let us know if you need anything and we will provide it to you.

2. Expert: It means they attacked, they were driven off by us and then they went to hasty defenses. A hasty defense to me implies that they are going to go into either an offense again, into an attack mode, or they're going to wait until reinforcements come up, but they're not really going to be in a defense very long. Also, a company size force reinforced with tanks means that to me that what they were going to do is probably fairly important.

3. Elicitor: Because of the reinforcement with tanks?

   Elicitor tries to determine the critical feature that led to the expert's conclusion.

4. Expert: Yes. In other words, they don't do things also, where if it's just a company size force, it's a straight motorized rifle or straight infantry force. That means they probably think they can accomplish whatever mission they were sent out with, with the forces they had and it's probably not quite as important as something that is tank-reinforced.

5. Military Consultant: What other thing might that be though?

Military Consultant looks for additional interpretations.

6. Expert: It also might mean that it's part of the supporting attack and it's probably reporting an attack and they wanted to have enough forces there to overwhelm the friendly forces. It also implies that they felt that they didn't have enough firepower and enough of a force there to overwhelm the friendly force with their own organic assets. The indicator is they didn't think the company could to it by itself so they attached tanks to it to do that. It could be one of those two things. It depends on what kind of context that you look at.

7. Elicitor: Have you made any assumptions based on this piece of information? We haven't told you who you are fighting or anything like that or what level you're at.

Elicitor wants to know if expert has generated any assumptions or context given that he has been provided with none.

8. Expert: I'm at least at brigade level.

9. Military Consultant: Why do you say that?

10. Expert: Because they deal with companies primarily. I could be at battalion, but I doubt it because usually the type of reporting I get when I'm a battalion S-2 I talk about squads and platoons. If it's a company size force, it implies to me that the battalion S-2 is reporting to me out of brigade and I have this size force attacking me at this particular point, and this is where the center mass of that company is, but there's also another implication here, too, that reminds me, simply because you have a six-digit grid doesn't mean that that company is all scrunched up right there, that they're on the line. It could be five hundred meters on either side. That just means that that unit is center mass and one tendency that we have in the Army is when we teach people that they don't realize that there is a lot of gaps but also when someone says something is a certain location, that means that unit is the center part of that unit and it's spread out on either side of that center point on whatever orientation they are on.

11. Elicitor: If it's spread out wider than normal, do they let you know that somehow?

12. Expert: The only way I can get any indications of that is to have an indication of what's on the flanks of that unit. It depends on where that center mass is of the flank units. The implication of this is I'm defending from the southwest, that means I've come from the southwest and they are coming from the northeast which means they probably have a general orientation of probably to the east and I have one to the west. I know it's in Germany so.

13. Elicitor: Why do you know that?

14. Expert: Because of the Leidenhofer Kopf. That's German.

15. Elicitor: Do you know who the enemy is?

Elicitor wants to know if there is an enemy associated with that location.

16. Expert: No, I can't tell.

17. Elicitor: Do you have any idea if you think you're fighting in Germany and tanks?

Elicitor asks the question again, using previous conclusions as additional context.

18. Expert: Well, I am assuming it is Soviet because we've been conditioned to think it's Soviet but it's not necessarily so. It's probably Warsaw Pact, I can say that probably. Unless, of course, we'd gone to war with West Germans and the French. But I can assume that it's a Warsaw Pact force because it's fighting in Germany and that's the only type of force we ever fight in Germany is a Warsaw Pact force. Now a Warsaw Pact could be one of four countries; it could be East German, Soviet, Polish, or Czech, depending on the location of this particular fight.

19. Elicitor: Is there anything that we could give you that would help you make more of this report than your ability to right now?

Elicitor wants to see how expert would proceed in his problem solving.

20. Expert: I need to know what echelon I'm at.

21. Elicitor: What would that do for you?

22. Expert. That gives me an idea of what size of forces I need to know from that point. In other words, if it's company size forces, then I'm right at the level that my brigade commander needs to know. He needs to know the company size forces. He needs to know the composition of those forces too. I need to know the composition of the forces that are on the flanks of this unit and what composition of forces there are behind this unit, because this implies and this is also another implication I get from this--that is, since it's reinforced with tanks, it's an infantry unit. So, when I graphically portray this, I'll say it's an infantry company plus. Because we don't reinforce tank companies with tanks. We reinforce tank companies with infantry, so it implies it's either... an off/on thing. So, if you see tanks reinforced with tanks, that means that this basic unit is infantry.

23. Elicitor: So you need to know what echelon you are at?

24. Expert: Right. The reason I say that is, that way if I know I'm at brigade level then I need to know, let's say, you had a company size force at this location reinforced with tanks doing a limited objective attack. What happened on either flank?

25. Elicitor: I'll give you that piece of information. You're at the division level.

26. Elicitor: First of all, knowing that you're at division level, what does that tell you now about this?

Elicitor wants to know how new information helps expert.

27. Expert: It tells me that this is a limited counterattack, possibly. In order to confirm that I need to know what the battalion that it was assigned to is doing. Is it defending, or is it on the attack? My immediate thing is that it was a counterattack because you're talking about a company size unit. At divisional level, I'm interested in battalions. That means that a company within that battalion that I'm interested in is doing a limited counterattack. What are the other companies doing within it and what are the battalions on either flank doing at the same time? So what I need to know from you almost immediately is what is the enemy doing, is it in the offense or the defense?

28. Elicitor: I'm not going to tell you that because that is a big piece of information. We're only going to give you little pieces at a time.

A key feature of this technique is that the expert must build his context slowly; hence, the elicitor does not want to give out "large" pieces of information.

29. Expert: OK. That's the key question that I'm trying to think of right now.

30. Elicitor: So you're trying to put together a picture in your head of what the enemy is doing.

    Elicitor tries to determine expert's objectives or problem-solving strategy.

31. Expert: Right. Also, I'll tell you one assumption that I can make here and I think I'm fairly confident about this and that is that the company that this belongs to is motorized rifle battalion. The reason that I assume that is we have a motorized rifle company that is being reinforced with tanks. Tank battalions don't do that. They do not reinforce with tanks. So I can make a fair assumption that what they've done is they have taken tank company out of a tank battalion, the regimental commander has taken a tank company out of the tank battalion, and given it to this motorized rifle battalion. The motorized rifle battalion commander then has broken out those tanks to the company size elements. So one of the pieces of information that I think I already know is that this is a motorized rifle battalion. What I need to know from that point on is I need to know if those battalions on either side motorized rifle or tank. The reason I need to know that is if I know that there is a motorized rifle battalion on one flank and there's a tank battalion on the other flank, then my next question is going to be, is this tank regiment, are these the first echelon battalions of this motorized rifle regiment, or is it a tank regiment?

In paragraph 1, the data presented describe an unsuccessful attack by a company sized force reinforced with tanks. The force then went into a hasty defense. The expert begins (paragraph 2) by restating the data. He then described a hasty defense. He lists three inferences from hasty defense--the enemy will go into an attack mode, they will wait for reinforcements, and they will not be in a defense very long. This information can be used to construct a production rule with "hasty defense" as antecedent conditions:

If	enemy is in hasty defense, then
	they will be going into attack mode
or	they will wait for reinforcements
and	they will not be there very long.

The knowledge that hasty defenses are temporary ones can be stored semantically by assigning the property "temporary" to "hasty defense."

```
hasty defense
    |  has property
temporary
```

This is a good illustration as to how production rules can be derived from structures such as semantic networks or object frames. If an entity has a certain property or attribute, then inference rules can be generated from them. This can range from simple rules such as "If [entity], then [attribute]" to inferences that can be generated from those attributes (e.g., If defense is temporary, then units will have moved after X hours).

At the end of paragraph 2, the expert makes the inference that the attack was to do something important. In paragraph 3, the elicitor asks whether it is because of the tanks that makes the attack important. In constructing production rules, it is necessary to specify what the antecedent conditions are. The elicitor's question was directed at that. The expert acknowledges that the tanks were the critical feature and that if the attack had not been reinforced, then it would not have been as important (paragraph 4). Hence, we can construct a production rule:

```
If    enemy attack is reinforced with tanks,
then  objective of the attack is important (2)
```

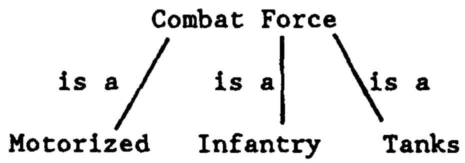
In paragraph 6, the expert elaborates on these by saying that the attack also could have been part of a supporting attack. Also, the enemy felt the attacking forces would not have been strong enough to overwhelm the friendly force; hence, they were reinforced. In light of the alternative interpretation of the reinforcement, we modify the above production rule to include both interpretations:

```
If    enemy attack is reinforced with tanks,
then  objective of the attack is important (4)
or    the attack is a supporting one and more force
      is needed to defeat enemy (6)
```

There is a more general rule that the expert discusses--namely, that when the enemy does not have enough organic forces to conduct its attack, it will attach other forces. This gets represented:

```
If    enemy has insufficient organic force to
      conduct a successful attack,
then  it will attach other forces to the fighting force (6)
```

As noted in our theoretical discussion of production rules, we can use such a rule to derive the inference that if they reinforce, then they thought the force was not strong enough to perform its attack. A useful observation is worth making. The expert is discussing different combat forces and labels motorized rifle, infantry, and tanks as different types of forces. Hence, we can use this to construct semantic nets:



In paragraphs 7-10, the elicitor and expert discuss assumptions the expert is making based on the information. He states that he assumes that he is at brigade level or higher since they deal with companies. He further elaborates that he would expect a battalion S-2 to get reports on squads and platoons. Finally, he assumes the battalion S-2 is reporting to him at brigade level. This information can be used to construct production/inference rules about who deals with what level unit.

If report is about companies,
then assume at brigade level
and assume report is from battalion S-2 (10)

If person is battalion S-2,
then will get report on squads and platoons (10)

The expert then (paragraph 10) says that he assumes that the grid coordinates he receives about the units are the center of mass of those units and that they are spread out around those coordinates as opposed to all being located at that particular point. He further specifies that the unit may be spread out about 500 meters on either side of the grid coordinate. This can be represented in the following production/inference rules.

If grid coordinates are given for a unit,
then assume they are the center of mass for that unit and that the unit may be dispersed around that center (10)

If the unit being reported is a company,
then it might be spread out around a 500 meter radius from the coordinates reported (10)

Note that this first rule is actually a more generalized version of the second rule. This relationship can be captured by noting that a company is a type of unit. Hence, by expressing this semantic relationship, the two rules can be linked.

> If grid coordinates are given for a unit,
> then assume they are the center of mass for that unit and that the unit may be dispersed around that center (10)
>
> is-a
>
> If the unit being reported is a company,
> then it might be spread out around a 500 meter radius from the coordinates reported (10)

In paragraph 12, the expert responds to a question concerning how to determine the dispersion of units. His response is to look at adjacent units. Unfortunately, he changes the subject without elaborating on how, specifically, looking at adjacent units will help make this determination. We can make some guesses, e.g., assume that the enemy creates a gapless wall; hence, take the distance to the next unit and divide by two (assuming both units are spread out equally). Unfortunately, in our determination, too many assumptions need to be made on our part in order to generate a detailed rule for this. At best we can generate a general (and perhaps useless) rule.

> If goal is to determine degree of dispersion of enemy unit,
> then look at flanking units (12)

The expert continues (in paragraph 12) to draw inferences to where the attack is coming from and where he is fighting (in the scenario). Since the enemy attack came from the northeast, he is inferring he is defending from the southwest. We can generate production rules for this, either for every specific cardinal point or just a general rule that if the attack comes from one direction, then the defense is from the opposite direction. This is a rather common-sense rule. The expert also assumes that he is fighting in Germany, because of the German name of the enemy's objective. There is another common-sense rule which is "If enemy attacks objective with German (or more generally, "country-associated") name, then assume battle is in Germany ("country")." This rule is probably not of much value since realistically, a member of the G-2 staff would never have to infer what country he is in. Similarly, it is of limited use to store rules of the form, "If name of something is "X," then it is part of "Y" language."

In paragraphs 15-18, the elicitor tries to see if the expert can infer who the enemy is, based on information the expert already has (i.e., he is in Germany and has fought tanks). The expert responds that he is fighting a Warsaw Pact country in Germany and lists four possibilities, with the Soviets being the most likely enemy. This can be represented by a combination of production rule and semantic network formats:

If fighting in Germany,
then opponent is Warsaw Pact, probably Soviet (18)

is a | is a | is a | is a

Soviet | Polish | East German | Czechoslovakia

In paragraph 19, the elicitor asks a question intrinsic to this technique--namely, what additional information the expert would like. This is so that he can determine how the expert is putting together the situation. The expert replies that he wants to know what echelon he is at (paragraph 20) since this will tell him what forces he needs to be concerned with. He gives as an example, that if he is at brigade, then he needs to know about company size forces. This can be captured in the following production rule.

If the commander is at brigade level,
then he needs to know about company size forces (22)

Actually, the expert switches back and forth from talking about what the commander needs to know to what the expert himself needs to know. This suggests that the rule should really be more general to include intelligence analysts (and possibly others as well).

The expert discusses the need to know the composition of the forces and the composition of forces on the flanks and behind those first forces. This gets a little tricky because this discussion is done in the context of a brigade commander, although it is probably the case that this rule applies to all echelons. Again, the expert changes the topic before this can be pursued; hence, we represent only what he has said and perhaps draw the inference ourselves and label it in parentheses as we have been doing. The way to represent the inference that other echelons care about composition of forces, etc. is to use a semantic net representation (which is useful to represent generalizations with "isa" links):

(If commander or intelligence analyst is at an echelon,
then he needs to know about composition of units that he is fighting and composition of flanking units and composition of rear units) (22)

is-a

If commander or intelligence analyst is at brigade,
then he needs to know about composition of units that he is fighting and composition of flanking units and composition of rear units (12)

The expert then goes on to infer that since the unit in question (the one conducting the attack) was reinforced with tanks, then the unit itself was infantry. He also lists the rule that tanks get reinforced with infantry. Hence, we have two production rules:

If unit is infantry and it is to be reinforced,
then it will be reinforced with tanks (22)

If unit is tanks and it is to be reinforced,
then it will be reinforced with infantry (22).

In paragraph 24, the expert gives an implication that being at brigade would have in terms of what type of information he would need to know; namely, that if a company conducts a limited objective attack, then he needs to know what happened on the flanks of that company. We can represent this by a production rule:

If echelon is brigade and enemy conducts a company size, limited objective attack,

then brigade personnel need to know what happened on the flanks of that company (24)

It can be assumed that there would be a more generalized rule of this form which varies the echelon (e.g., division, battalion, etc.) and the size of the enemy force that it would be concerned with (e.g., battalion, platoon, etc.). However, the expert does not give this information and it cannot really be inferred from the text. This might be a question that would have been good for the elicitor to pose.
When the expert is told that he is at division level (paragraph 25), he infers that the attack by the company was a limited counterattack. He states that in order to understand this better, he would need to know what the battalion the company is assigned to is doing. Presumably, (although the expert does not state so specifically), if the battalion as a whole were attacking then the attack was for a much larger objective. This lends us to infer the following rule:

If the enemy is conducting an attack,
then the size of the attacking force is proportional to the size of the objective. (27)

The expert also states that since he is at division, he is interested in what the battalions are doing.

The expert also states that since a company within a battalion is conducting the attack (instead of presumably the whole battalion), it is a limited objective attack. We can construct a rule from this:

If a battalion uses only one company to attack,
then it is likely to be a limited objective attack. (27)

What is interesting here is that there may be a more general rule, which is if a unit uses only a portion of its subunits to attack then the attack is a limited objective attack. Note that this rule is similar to the above-mentioned rule that states that attacking forces are proportional to their objectives. This suggests two dimensions that can be used to infer enemy objectives. Absolute size of force and proportion of force. However, both of these dimensions result from inferred rules so we cannot use this as a mode of the expert's knowledge.

Some support for this general rule that we propose is given by the expert's request to know what other units are doing. Presumably, if many units are attacking then the attack is a major one whereas if only the company is attacking, then the attack may be a limited objective attack.

In paragraph 31 (note that in the previous paragraphs the elicitor refused to give the expert the information he requested for fear that it might give away too much of the picture and undermine the purpose of the technique being used), the expert infers that the attacking company belongs to a motorized rifle battalion since tank battalions do not reinforce with tanks. This suggests two rules: first, that tank battalions do not reinforce with tanks, and second, [in this scenario] if a combat battalion is not a tank battalion then it is a motorized rifle battalion. These two rules are presented below.

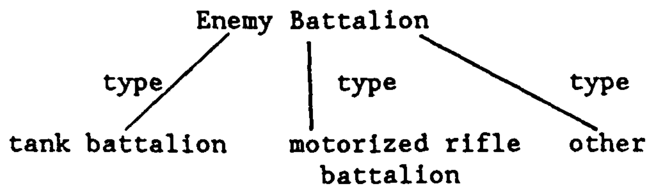
If maneuver unit is tank battalion,
then it will not reinforce its companies with tanks (31)

If enemy maneuver battalion is not tank,
then it is motorized rifle (31)

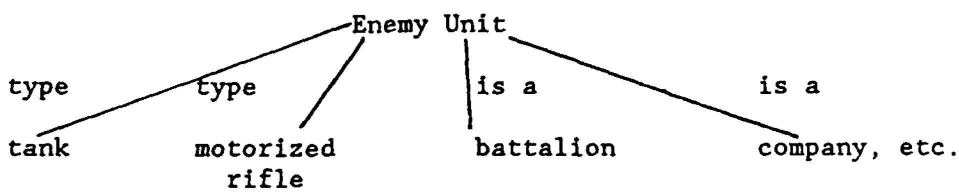
There are some interesting points worth noting here. With regard to the first rule, there may be a more general rule that tank units in general do not reinforce their subunits with tanks. A question here is whether there are constraints on what this subunit can be. For example, a company is one echelon lower than a battalion. Does this first rule apply to only those subunits one echelon below? Such information might be listed semantically by listing features of the units that do not get reinforced. Another interesting question would be whether an infantry battalion would reinforce a company with infantry, thus perhaps creating a general rule that units do not reinforce subunits with the same forces as the type of unit they are. Such questions may have been useful to pursue with the expert.

An interesting and more general issue arises with the rule that if an enemy battalion is not tank then it is motorized rifle. In addition, to the question of whether the rule is general (i.e., if division not tank then motorized rifle, etc.) and also the question of whether it is

complete (i.e., in same contexts, there could be airborne combat units) there is also a more fundamental question as to how the expert arrived at that conclusion. Does he store the two possibilities in the form of separate rules? Another possibility is that he knows that there are two types of units so that if it is not one unit then it must be the other unit. One way to capture such knowledge would be through the use of semantic networks and "type" links as depicted below.



If we focus on a simple case with only tank and motorized rifle units at any level, we could use:



Again, such information might have been useful to pursue with the expert. The expert gives a scenario as to how the reinforcement process may have proceeded. Actually, he lists a set of procedures that may have been followed. These are best captured by production rules which can be taken directly from the text:

If goal is to reinforce subunits and unit is regiment,
then take tank company from tank battalion and give it to motorized rifle battalion. (31)

If goal is to reinforce subunits and unit is motorized rifle battalion and has been given tank company by regimental commander,
then give tank platoons to motorized rifle company. (31)

There are two things to note here. In the second rule, the expert does not explicitly say to give the tank elements to a <u>motorized rifle</u> company. However, in paragraph 22, the expert says that only motorized rifle companies get reinforced with tanks. Hence, we are justified in making this modification to the rule. The second thing worth noting is that these rules form part of a common procedure. The way to tell this is that the antecedents of the second rule depend on the consequential

conditions of the first rule being met. Another consideration is that there is a common goal or antecedent condition to both rules. This is what is known as chaining production rules to form a larger procedural sequence.

Having inferred that the unit the company belongs to is a motorized rifle battalion, the expert wants to know what the adjacent battalions are so he can determine the type of regiment that is there. The first thing this tells us is something about the hierarchy of units, namely that companies are part of battalions which in turn are part of regiments. We can represent this by using semantic networks and "has-part" links:

```
Regiment
     |has-part (31)
Battalion
     |has-part (31)
Company
```

Given this hierarchy and the fact that the expert wants to infer higher-order units from its parts, we can infer a rule that one can infer the whole from its parts. This turns out to be a rule which experts used frequently throughout the problem. Such a rule is more of a general problem solving strategy than a specific procedure or inference rule. This demonstrates that production rules can be general and high-level as well as specific and low-level.

It is interesting at this point to summarize how the expert's problem solving process evolved using this generative procedure. A remarkable amount of material has been generated given that only one piece of data was given initially. The expert began with generated "immediate" inferences from the data, e.g., features of a hasty defense, why tanks would be used to reinforce the company that was attacking, etc. The expert then went on to make high-level inferences such as what echelon he was at and how serious was the attack given its size. Each round of inference generated new questions for the expert and it was clear that these questions moved away from the information he had and more toward a larger picture. For example, the expert started forming hypotheses about the higher-level (battalion and regiment) units he was facing and became more interested in the adjacent units as well. It seems as though the flow of the expert's reasoning was to first make inferences off the data he was given, infer immediate cause of the events in the data (e.g., was the goal a limited objective attack?), look for a larger framework to put the events into (what are the other units doing?), and generate some hypotheses (e.g., the regimental commander is making a tank company available to the battalion commander for attack).

It appears that this expert, anyway, has a wealth of low-level knowledge he could bring to bear on the data he received and was able to start forming the framework of a larger picture based on this knowledge. His knowledge for doing this scenario was largely representable in terms of semantic networks and production/inference rules, some of which might be derivable from semantic networks.

7.2 Extended Databases

In Appendix D we present preliminary formal knowledge models for each domain constructed from protocols taken from both interpretative and generative methodologies. These knowledge models must be considered highly tentative, since they reflect the results of only a limited amount of time at the early stages of an elicitation process. These models are constructed from those subjects in each cell (interpretative/situation development, interpretative/order of battle, generative/situation development, generative/order of battle) whom we considered to be most expert. This determination was based on three considerations: the type and amount of experience the subject had in the relevant problem area; the subject's own assessment of his expertise (a few subjects actually admitted that they did not have much experience in the problem area); and the project team's (including the Burdeshaw consultants) assessments of which subjects seemed to be most expert.

We present data bases for each of the four cells described later in Appendix D. A qualitative analysis of the databases, including evaluations of the different elicitation methods and how they interact with problem areas, in Section 6.0. The data bases themselves were constructed by assimilating the knowledge representations constructed by individual subjects in each cell. The inclusion of elicited knowledge in the database reflects that it was presented by the "expert" and is not an indicator that it is 100% accurate.

8.0 SUMMARY

The research described in this report reflects an approach to knowledge representation and expert knowledge elicitation that is based on cognitive theory. The goals of our first year's work have been to develop methods that utilize either an interpretative (top-down) or generative (bottom-up) orientation to knowledge structuring, and expert knowledge elicitation, and to investigate and compare the effectiveness of interpretative versus generative methods of knowledge structuring and elicitation through studies with army intelligence experts.

Interpretative knowledge provides a goal-driven approach to specific problem-solving, and allows for formation of expectations and assumptions when reasoning under conditions of uncertainty. Domain knowledge of this type can be rather generalized or abstract in form and may be organized hierarchically to capture this type of knowledge. Our interpretative approach to knowledge representation incorporates the use of scripts, object frames, and mental models. The interpretative approach to knowledge elicitation we developed and tested involved semi-structured interviews with army tactical intelligence experts which included a discussion of strategies and procedures for problem-solving based on a specific army training exercise.

Generative knowledge is organized around low-level rules and concepts in the absence of a particular context. Problem-solving with this orientation revolves around individual pieces of data or problem-solving procedures, generating a framework by combining individual pieces. To capture this type of knowledge, our generative approach to knowledge representation incorporates the use of production rules, semantic nets and mental models. The generative approach to knowledge elicitation that we developed and studied with army intelligence experts involved a "data-oriented" problem solving. This entailed having the expert work on a specific army training scenario in the absence of the background and contextual information he would normally have access to, by being given individual pieces of data from the problem and being asked to respond to the data in terms of what each piece implies for the current status of the problem and the direction of future problem solving steps.

8.1 Summary of Findings

Findings from our initial research studies with the generative and interpretative methods that we have developed will be described in terms of the overall efficiency of these methods and the interaction of method effectiveness with the characteristics of our test domains of Situation Development and Order of Battle.

8.1.1 General observations on elicitation methods. In general, the experts we interviewed using either an interpretative or generative approach to elicitation appeared to make use of both generative and interpretative knowledge to guide problem solving, although the reliance on one sort of knowledge versus the other varied with individuals and domains. For example, situation developers, as we anticipated, generally

appeared to make greater use of generative knowledge than did order of battle analysts, who typically do not have to integrate as many different bodies of knowledge to produce their assessment. Situation development also had an important interpretative and goal-oriented component, however, since the assessment is done to support the commander's mission and intentions. The order of battle analysts appeared to make extensive use of their knowledge of various enemy force, doctrine, and operational templates which was highly frame-oriented and interpretative, but they had to use a stream of detailed report data to build a specific OB assessment, and this required a generative knowledge organization.

These findings suggest that a more efficient approach to knowledge elicitation would be one that incorporates *both* the generative and the interpretative methods we have developed.

With respect to elicitation efficiency, it was also found that all of the methods we studied were most efficient, in terms of the quantity and quality of knowledge obtained, when used on subjects having the most skill and experience in the target domain. For example, the analysis of order of battle interview data indicated that the number of inferences and hypotheses that could be generated from the data was closely related to the subject's level of expertise. Correspondingly, the efficiency and effectiveness of methods seemed to decline in proportion to the subject's apparent aptitude for problem solving and/or level of practical experience in the target domain. This suggests that a very careful screening of potential experts should be carried out in order to identify the real experts prior to conducting extensive interviews; this will maximize the efficiency of the elicitation methods that are used.

8.1.2 Elicitation methods and test domain characteristics. The following discussion summarizes our observations on the use of our interpretative and generative methods in the domains of situation development and order of battle analysis. Knowledge used in these task domains was obtained in interview sessions that involved the use of either an interpretative or a generative approach to elicitation.

The analysis of protocols from the *interpretative* elicitation of situation development knowledge indicates that this approach captured a lot of goals and scripts but very little in the way of specific procedures. Although the interpretative approach elicited few specific procedures for situation development, the responses of subjects often contained production rules, since some of the actions in their scripts are situation specific. The interpretative method also revealed an extensive use of organizational or systems knowledge in situation development. This knowledge enables the analyst to effectively coordinate his actions and exchange information with other actors in the intelligence staff and in other functional areas. It also became clear that there was an organizational component to the analysts' task that involved a sort of quality control; seeing that information is gathered and processed in an efficient and timely manner.

The situation assessments produced (for the training scenario) in the interpretative sessions seemed rather general in terms of the conclusions that were drawn by the analyst. But this was basically

consistent with the level of knowledge targeted by the interpretative approach and with the situation developer's basic problem-solving orientation. The SD analyst would gear his reporting toward support of his commander's mission and intent and the commander's level of problem focus. The analysis of data from the interpretative elicitation of order of battle knowledge yielded more detailed procedure descriptions than those obtained with situation developers. Since our methods were consistent across domains, this variation appeared to reflect a normal use of more detailed and highly specified procedures in order of battle analysis. To capture the extensive use of these rather standardized and detailed procedures, the interpretative approach needs to provide a rule-like structure, or this deficiency could be remedied by the integration of the currently defined interpretative and generative knowledge structures. Interpretative elicitation for order of battle analysis indicated that problem-solving in this domain involves relatively more top-down structured knowledge than situation development. Order of battle analysts, for example, have a rich store of frame-oriented knowledge about enemy force structures, weapons, and equipment characteristics, commanders' personalities and so on.

The analysis of data from situation development and order of battle elicitation sessions using a *generative* approach indicates that this bottom-up approach effectively captures a lot of rules of inference and action. Components of semantic networks were also obtained, along with their linkages to rules. On the other hand, this method of elicitation obtained very few mental models. It seemed that the use of such models would be fairly difficult to detect since their use may be fairly automatic and they may be expressed in a "compiled" (Neves and Anderson, 1981) form that would be expressed very much like a production rule. If the running of the model has become automatic, then the subject would hardly be aware of its use. The detection of such models, and attempts to recover the full and uncompiled version of the model, would therefore depend on the initiative and the level of domain expertise of the elicitor. Whether eliciting rules, nets or mental models it appears that our method should require subjects to be even more specific and detailed in the description of their knowledge. The level of description we have so far obtained is not sufficiently detailed to guide processing in a knowledge-based system. Although a large number of rules were obtained with our generative method, the rules would often be fragmented, since the bottom-up method did not address the construction of a broader framework in which to place these rules. This finding supports the need for an elicitation method that integrates top-down with bottom-up approaches to knowledge organization and elicitation.

Throughout our interviews, order of battle analysts generally appeared to rely more upon standard reference manuals and force templates to accomplish their task. Their inferences and actions appeared to be following army doctrine rather closely. Situation developers, on the other hand, tended to rely less upon standard procedures and official doctrine. Their problem solving procedures appeared to be more dependent on both their commander's particular mission and intentions and the specific features of the battle situation. The observations were

consistent with our initial hypothesis that situation development would be more generative and order of battle would be more interpretative in terms of the direction and control of problem solving.

With regard to the performance of elicitation methods across individuals, responses to the interpretative approach were rather well-correlated in terms of the scripts and object frames elicited from individual experts within a domain. Responses to the generative approach to elicitation were more varied. Individual experts differed both in terms of what they would infer from a given piece of data and how many inferences a given piece of data would trigger. When the relationship between these response variations and variations in the level of expertise is better documented and better understood, this approach to elicitation might have additional value as a tool for preliminary screening of experts for subsequent and more extensive elicitation.

Our elicitation studies in the domains of situation development and order of battle analysis have also made us more aware of another important and challenging dimension that must be considered in the development of effective methods of elicitation in tactical intelligence. Both of these task domains exist to support the problem solving of their echelon commander. Using the terminology of cognitive psychology, OB and SD analysts provide the commander with an assessment of the current problem state and assessments of the relative efficiency and likely effectiveness of various strategies (i.e., friendly courses of action) for reaching the goal state which is the accomplishment of the commander's intention. Battles not only involve relatively static objects such as terrain force elements and equipment, they are fought across dimensions of space and time. Indeed, the spatial and temporal dimensions of battlefield assessment play a critical role in the problem solving. Temporal considerations in a highly dynamic (e.g., high intensity) combat environment affect the information value of the report data that is received: what inferences can be made and the level of confidence in one's assessments. Evaluation of the battlefield is based not only on inferences about the composition and strength of forces but their arrangement on the battlefield. Different assumed configurations of forces can have very different implications for the intelligence assessment.

These features of the tactical intelligence domain offer special challenges that are not adequately addressed with current approaches to expert knowledge representation and elicitation, and subsequent processing within an expert system. The second year of our research will thus include efforts to develop structures to capture spatial and temporal dimensions of intelligence experts' knowledge and strategies for problem solving, and the integration of these sources of knowledge with other knowledge components. Another related but broader representation and elicitation issue that we will pursue in our Phase II work concerns experts' formation and use of inferences and assumptions (including spatial and temporal factors that introduce additional sources of uncertainty) in the course of developing intelligence estimates.

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APPENDIX A

KNOWLEDGE ELICITATION IN MICROCOSM: A PRELIMINARY SESSION WITH A G-2 EXPERT ON INTELLIGENCE COLLECTION FOR AIR-LAND BATTLE

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APPENDIX A

CONTENTS

1.0 INTRODUCTION

1.1 Purpose of Exercise

This report discusses an attempt at "microcosm" research as part of a larger project on knowledge elicitation methodology. Microcosm research is a "bottom-up" approach to generating and testing theory and methodology, which focuses on specific instances of the real-world they are to apply to, and explores the application of candidate ideas.

In this project, we are concerned with developing methodology to elicit knowledge which will ultimately be used in particular situations, for particular purposes. A major part of the research effort is *deductive* in spirit in that it is to develop general theoretical principles yielding elicitation techniques which can be adapted to specific cases.

However, in parallel, we have begun pursuing a more inductive approach, working back from specific instances in the real world (or as close to the real world as we can get), which suggest methodological (and even theoretical) insights. That is the focus of microcosm research. While each approach can be pursued independently, interaction between the two may provide fruitful cross-fertilization. The inductive approach uses whatever the current state of the art in knowledge elicitation technique is, which can incorporate. In return, inductive exercises can generate suggestive insights for the deductive phase. To use an analogy from engineering design, we can develop our methodology using the principle of "build-test-build-test."

The first step in the inductive approach, which we report here, is to identify a single army situation representative of a knowledge elicitation task to which our tools of knowledge elicitation would ultimately be applied.

Specifically, seven "knowledge elicitors" from Decision Science Consortium, Inc. and Smart Systems Technology, Inc. met with General Ennis Whitehead, of Burdeshaw Associates Ltd. for about four hours on the morning of November 24, 1986. A transcript of that session appears as Appendix A; and comments keyed to specific places in the transcript are given in Appendix B. Appendix C shows materials issued in advance of the session--notably guidelines on its conduct; and Appendix D shows review memos from four participants at the session, including a summary in Appendix D-1.

Our working assumption at the time was that we were developing knowledge elicitation techniques for a particular purpose, viz. eliciting knowledge from an experienced G-2 for the purpose of enhancing the training of a less experienced officer preparing to take up the post of Divisional G-2, in the early stages of an east-west air-land battle in Germany. The knowledge elicited, therefore, did not need to include the knowledge the "trainee" G-2 had already learned as part of regular school training plus field exercises. There was thus no presumption that the knowledge elicited would *replicate* the expert; it would only capture knowledge incremental to that of the trainee.

This implies, effectively, that there would be no scope for the knowledge to be embodied in a computer program to replace any existing function of a G-2 (which would have to include the"training base knowledge"). Indeed, there was also no presumption that the knowledge would be represented in any particular medium or form (such as expository text or computer code).

We were later given to understand that our primary focus should be somewhat different from what we had assumed: the domain of knowledge should be intelligence analysis more than collection; the knowledge to be enhanced was junior to that of the G-2 (e.g., S-2); the vehicle for communicating the knowledge should be computerized. Nonetheless, the case illustrated is still of some interest and some of the insights generated can be usefully generalized.

1.2 Format of Exercise

Ennis Whitehead, previously a G-2 himself, served as the expert subject and we spent four hours with him tapping into his expertise in intelligence collection management in situations typified by a certain hypothetical scenario, which we dubbed "the Treysa defense scenario." It was a scenario which had been prepared by the Army for the purpose of exercising the skills of a G-3, and written up at the level of detail relevant there. General Whitehead was asked to familiarize himself with the Treysa defense scenario ahead of time, and to give some limited thought to what kind of guidance he would be in a position to give to a trainee.

The ground-rules for the session, issued to the subject and to the elicitors, is given in Appendix C-1 and the subject's initial statement of relevant knowledge is given in Appendix C-2. After the session, participants were invited to give their comments on what they thought they had learned which was relevant to developing a theory or methodology of knowledge elicitation, or to the direction of the research project. Four of these are given in Appendices D-1 through D-4, of which the first also summarizes the content of the session.

General Whitehead was first asked for any general guidance on intelligence collection management that would be helpful to the trainee G-2, which were based on some notes he had prepared (Appendix C-2). He was then asked to provide more specific guidance on a priority intelligence requirement which he judged to be of critical importance: uncovering and predicting the movements of the enemy's reserve forces. Specifically, he was asked to focus on what he would recommend the G-2 do at 0600 the morning of August 19th in the hypothetical scenario, by way of intelligence collection, to determine whether the enemy's 9th division or 7th tank army was stationary or advancing.

Up to this point, no particular effort was made to adopt any specific knowledge elicitation technique. All questioning by the knowledge elicitors was unstructured and opportunistic. Both they and expert were encouraged to interject procedural comments or questions on the process of eliciting knowledge itself.

The latter half of the morning was devoted to trying out some more structured elicitation approaches. The first was an essentially generative approach, "step-through simulation," where the expert responds to a specific unfolding of the scenario, indicating what he would do as G-2 and commenting on why (see Section 3 below).

The second was an interpretative approach, involving top-down elaboration of goals from overall mission down to tactical steps (see Section 4.1).

A tentative effort was made to pursue another interpretive approach, that of imposing a decision theoretic structure on the elicitation (see Section 4.2).

Most of the useful content of this exercise is contained in the comments and reviews in Appendices B and D. Since they are intended to be, at most, suggestive and unconstrained stimuli to the imagination, no attempt has been made to seek closure, or even convergence, IN this first step in a divergent process. Nevertheless, we have culled a few of the more interesting hypotheses and insights generated below.

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2.0 OBSERVATIONS ON UNSTRUCTURED PHASE OF SESSION

2.1 On Knowledge for Battle-field Intelligence Generally

- Elicitation methodology cannot be usefully developed without a clear understanding of the use to which the resulting knowledge is to be put.

- The complexity, variety and subtlety of knowledge at the G-2 level makes computerized replacement of any significant class of his judgments--whether of inference or decision--unpromising. Therefore there is little scope, or need for, eliciting knowledge in a computer-codable form, at that level.

- Although at the outset of a war, a G-2's knowledge is driven largely by the (interpretive) doctrine he learned in training, he expresses this knowledge most readily as *instantiations*, i.e., even more generative than production rules.

- However, the only compact, yet comprehensive, way to capture this sprawling instantive knowledge may be by imposing a formal logical discipline (e.g., decision theoretic) on the elicitation--even if it does not fit naturally the subject's cognitive style.

- The appropriate method of elicitation may depend on whether the subject is teacher (interpretive?) or a doer (generative?).

2.2 On Knowledge for Intelligence Collection Management (ICM)

- Although *Substantive* knowledge for decision making, such as ICM is, may be too situation specific to be usefully elicited ahead of which it is needed, however, *procedural* knowledge on how to make such decisions may be usefully elicited, and perhaps computerized (e.g. some version of the "decision tables" used by some G-3s for evaluating major courses of action). There may be less scope for transferring procedural knowledge for the more evolutionary ICM decisions.

- This may be a way of eliciting the knowledge engineer's knowledge to *enhance* the judgment of the intended G-2 "client" (as opposed to *replicating* the (substantive) judgment of a more expert G-2).

2.3 On Knowledge for Intelligence Analysis

- Inference judgment, such as intelligence analysis is, lends itself more readily to using knowledge that can be elicited in advance from an expert, in being less situation-specific.

- Procedural knowledge that may be worth eliciting from knowledge engineers, to be made available to G-2s or S-2s in the field may include aids for fusion of conflicting intelligence reports, or for eliciting relevant judgments from *staff* colleagues or subordinates (though that knowledge may need to be developed first before it is suitably adapted to battlefield conditions).

- The most promising form of substantive knowledge elicitation may be commonly recurring and relatively constant elements of intelligence analysis, such as the computation of force ratios and low level rules of thumb, that may be taken straight out of doctrine (i.e., the knowledge is not necessarily elicited from a single human expert).

3.0 A GENERATIVE APPROACH: STEP-THROUGH SIMULATION

3.1 What is Step-Through Simulation?

Step-through simulation is an analytic technique but similar in spirit to war gaming. It simulates possible sequences of acts and events which reflect experts' judgments of their likelihood (Ulvila and Brown, 1978). It was developed primarily to generate a sampling of possible aftermaths for a decision or situation, which is to be evaluated. The aftermaths are treated as if they were representative of the real future conditional on the situations.

It has many points of similarity with conventional Monte Carlo simulation. What distinguishes it from Monte Carlo is that the whole complex network of *possible* sequences and their probabilities do not need to be pre-specified, but are supplied by judgment as needed, as any particular trial sequence unfolds. This enables a much richer future to be explored, with much less elicitation burden (at least for a small number of trials).

Our intent, in this microcosm exercise, was to generate possible paths through the future development of the Treysa defense scenario, with two rather distinct objectives in mind. One was to present General Whitehead with a sampling of situations which would call for G-2 ICM action, so that he could indicate how he would respond to them and have an opportunity to comment on why. The other was to provide some basis for *evaluating* these choices, by simulating what their aftermath might be (much as would happened in learning from experience).

In either case, knowledge elicited is in the form of a hypothetical battle sequence (or set of sequences) that provide the arena for a surrogate for real experience involving apprenticeship to an expert.

If the purpose of the knowledge elicitation is, in fact, *training* (one of the purposes for which step through was originally designed), its mode of *use* would include the trainee proposing his own solution at each G-2 step, before learning the G-2's solution, rationale and simulated aftermath. A second expert (or the first if only one is available) could comment on the difference between the trainee's and the expert's solutions. Military practice in training officers has much in common with this approach. For example, submarine commanders are trained by participating in exercises (whether at sea or simulated by computer), after which there are "hot wash ups" (and critiques) by experts who have watched their performance in the *exercise*.

Of course, knowledge elicited in this form, only "stands in" for a *real* war sequence, which would be preferred if one existed and were documented. A distinctive feature of the knowledge being elicited here is that, although as expert as one can get, it is not grounded in any real experience of the type of war situation in which it is to be used. Even experience from participation in field exercises contains a significant element of the interpretive knowledge held by the exercise designers. If the real world is riding a bicycle, and doctrine is a book on cycling, a field exercise is cycling with training wheels.

3.2 How Step Through was Implemented Here

We asked the general to place himself in the context of the Treysa Defense scenario at 0600 on August 19, with the intelligence the scripted scenario says he has at that time. With that information, he is now asked to construct a plausible sequence of friendly, enemy and "natural" developments, starting at 1000 hours, given a decision by the U.S. division commander to go with "course of action three" (on the assumption that the commander has about four hours to make this decision from 0600).

The general was asked to play three distinct roles: generator of the real world developments which the G-2 is faced with (including friendly actions other than his own); his best response to these developments as a G-2; and critic of those G-2 actions. (If available, a different expert or a set of domain specific experts, would generate the external developments that the G-2 is responding to; both to make them factually realistic, and to avoid any biases that might creep in, due to the fact that the "player" and the "judge" roles are played by the same person. For example, there maybe a tendency for a G-2 to bias the aftermath of any decision has has proposed in a direction that would vindicate the decision).

The general's instructions were, at each point in time as the sequence unfolds, to: consider what developments *might* happen; identify which is the most probable; and assume that it has happened. In parallel, he was to consider what his reaction as G-2 would be at each point and discuss why.

Only a few steps in the step through simulation were followed (see transcript and comments in Appendices A and B). In particular we did not proceed far enough along to *evaluate* sequence (i.e., in terms that would enable one to say whether the actions taken turned out well or badly).

We did not exploit a major feature of step-through which is picking developments *in addition to* the most probable, in a way that reflects their likelihoods. Ideally, we would have extracted probabilities at each event node and sampled possibility.

3.3 Implications for Future Use of Step Through

If the purpose of step-through here were to evaluate a particular major choice, (such as which of three main courses of action to adopt), by modeling possible aftermaths to it, we would need a set of aftermaths, with their evaluated consequences, for each option, and make it as controlled an experiment as possible. Instead, we were primarily trying to generate representative experience for a G-2 for which a single sequence may be adequate.

The following would be a more powerful variant of step-through worth developing and testing, for the purpose of generating a library of training scripts for intelligence officers, emphasizing particular classes of skill or expert knowledge, which they embody.

The intelligence function at whose service the knowledge is to be put, is identified, say for intelligence analysis, in keeping with the current thrust of the project. An example might be the fusion of intelligence by an S-2 reporting to the G-2. More than one intelligence analysis function to be aided may be selected, each with its own expert (e.g., photo analyzer).

Sequences are constructed intended to capture the range of trainee actions be informed and the aftermath they might lead to. Each uncertainty, whose resolution constitutes a trial sequence would have its own simulation expert e.g., on weather, own force action, enemy action. Critical commentary by the same or different experts could be added at any time.

Various pieces of a trial sequence would be developed by the alternation of appropriate players in the simulation. The first trial would be modal i.e., each uncertainty is resolved at its most probable value. Subsequent trials would be drawn from the whole range of possibilities, in such a way that selection is proportional to their assessed probability. In this way the resulting trials can be considered as a random sample from all possible sequences. (More efficient sampling methods than simple random can be explored such as periodic or Latin hyper cube, but this is a refinement that need not concern us initially). The implementation of step through could be computer aided in the elicitation phase.

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4.0 INTERPRETIVE APPROACHES

4.1 Hierarchical Structure Approach

One of the approaches to interpretative knowledge elicitation that was tested during the latter part of the microcosm exercise involved questioning that followed a hierarchical structure. Ennis Whitehead was first asked questions about broad matters such as ICM goals and plans, and this was followed up by questions to "fill in" the more detailed levels of description, reasoning and action that constitute these aggregate-level objects and processes. The subject was again found to make extensive use of specific instantiations, either to rederive some of th broader concepts or to illustrate concepts for the elicitor.

4.2 Personalized Decision Analysis Model

4.2.1 Essence of approach. Any required judgment, such as a decision or an assessment, can be logically related to any other relevant judgments and data through a mathematical model based on statistical decision theory. In fact, any sound reasoned use of knowledge can be expressed in terms of such a model, expressed in a standardized form. In particular, uncertainties are expressed as probabilities, and value judgments or preferences as utilities (Watson and Buede, 1987).

This analytic technology, known as personalized decision analysis (PDA), offers two promising avenues for knowledge elicitation. One is to discern a logical framework underlying the expert's knowledge and reasoning on any particular issue, in order to fit formal coherent structure to it, that comes as close as possible to the subject's existing patterns of thought. This might be called *passive* structuring. *Active* structuring is where the knowledge engineer takes the initiative in determining the PDA model and uses experts (or any other source) to determine the most appropriate inputs.

There is a marked practical difference between the two. Passive structuring is essentially descriptive of an expert; merely constraining him to be logically coherent. In the active case, any given expert is only providing part of the input to a prescriptive model. No one expert would necessarily concur with the output and not all of any given expert's knowledge is necessarily tapped (if it is not in the form corresponding the preset model). Some of the knowledge the knowledge engineer himself develops (for example by analyzing data in ways that none of the "experts" have done).

In both cases, the expert's knowledge must be force-fitted into a language which may not be natural or comfortable; the language of probability and utility. There are possible inherent ambiguities of translation. There is also the problem of coherence and instability. What if, when probabilities and utilities have been distilled from the subject (expert), they prove inconsistent with each other? Procedures for reconciling and/or pooling incoherent judgments are currently being developed, (Brown and Lindley, 1986).

PDA models would appear to be examples of interpretive structures (at least when specific prescriptions or inferences are derived from normatives rules, statements of goals as utilities and probabilities).

4.2.2 Application in this case. A mild effort was made to fit the experts' judgment bearing on intelligence collection management into a PDA framework. There is a well established PDA paradigm for evaluating information gathering decisions (which this is), known as pre-posterior analysis (PPA). Basically this involves evaluating each information gathering option in terms of the findings it might generate, the actions these findings might lead to, and the probability and the cost of erroneous action, i.e., resulting from not having *perfect* information).

Part of the elicitation session was oriented towards eliciting the general's informal appraisal of these issues and to test whether his recommendations appeared to be driven by them. It did not appear to be a natural exercise for him even in purely qualitative terms, and we did not press the matter on this occasion. We could have pressed him harder to give us first qualitative and ultimately quantitative answers to the appropriate questions. It seems unlikely that we would thereby be capturing the way he in fact formulated his conclusions.

The focus of his thinking was that the most urgent intelligence need is to find out what the enemy's reserve troops are doing. However, he did not rationalize or verbalize the reason for this directly in terms of the of the costly errors that the Army division commander could make if they misjudged this. He verbalized it in terms of its being "the most serious threat." In fact, at it's face value this rule of thumb would seem to indicate that information about the divisions *already in contact* would represent the greatest threat and therefore merit, by this rule, the most intelligence attention. It appears that his judgment conforms to what the PDA *would* show, even though the *elements* of his thinking did not appear to conform to that model.

Although we were not, at this time, looking for knowledge on intelligence *analysis* there were a good many readings on the subject's inferential processes, since these are inextricably bound up with intelligence collection management decision.

It does not appear that he thinks in Bayesian updating terms. In particular, there was nothing in his thinking aloud that appeared to correspond to a "likelihood function" (i.e., assessment of the diagnostic value of particular items of information, expressed as conditional probabilities of observing the information, given possible values of the truth).

This is not to say that, in either the ICM or the intelligence analysis case, there were not perfectly valid PDA models, which the general's thinking reasonably approximated. On any given judgment, whether of choice or inference, there are many perfectly valid PDA models relating them to more primitive judgments and/or data. A more single minded effort than the dilettante elicitation session we had on this occasion might well yield one that fitted.

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ATTACHMENT A-1: TRANSCRIPT OF MICROCOSM ELICITATION EXERCISE 11/24/86

Subject: General Ennis Whitehead (BAL)
Elicitors: Rex Brown, John Leddo, Marvin Cohen,
Kathy Laskey, Theresa Mullin (DSC)
Craig Cook, Craig Will, Claire Cardie (SST)

(Numbers in paren refer to editorial comments in Attachment A-2. Asterisk indicates point of special interest.)

1. INTRODUCTION (1)

R: What I have in mind is to try to end up with a rapid pass at sample elicitation.

Our metaphor is: we're in the business of trying to design tools for geologic excavation. What we're doing here is taking a spoon and digging out a bit of earth and looking at it, that's the analogy.

So we're going to try to get breadth rather than depth and not seek any kind of convergence; even if we seem to be on a roll and can say "hey, I can see how we can really pick Ennis's brains thoroughly on that." I may divert us just to make sure that we've sampled all the major types of material. That will be, as the centerpiece Ennis is delivering (with some stimulation from us), knowledge that's representative of one class of information that we think this project is interested in.

We're going to want two types of material. First is Ennis's provision of material; but in addition, any of us, including Ennis, that have some side comments that are brief. For example, Ennis may want to say "Hey, that's not a natural question for me. If you'd phrase it differently it would help". So I don't want to discourage editorial comments. We'll need to make them brief, but it's more useful to have them made on the spot, particularly so that when the tape is transcribed it is a point to think about here. I'd also ask you, when you contribute, to mention your name so that the transcriber can keep us apart.

At the end of the session, we'll have a little time for recap, but what I'd like would be for anybody who has any comments that they'd like to share to write them down. Now the comments can be at all kinds of levels, including "hey, this isn't the kind of knowledge that we should be eliciting." If that's true then that's alright. Include also what would be a useful follow up to that. But generally, give anything that, taking off from this session, you might want John in particular to dwell on as he plans the rest of the project. Concrete.

We've asked Ennis to look at a particular area of expertise which is the management of intelligence collection. We've asked him to take the position of somebody training a G-2 that's getting ready to take up a post of G-2 in a situation like the Treysa Defense Scenario (2) that we'll be using as our concrete point.

Craig Cook: Is this training a person who's fairly new to the task, like it's their first assignment, or are they a highly skilled G-2 and they're just now getting briefed on the situation in this environment, having come from outstanding performance someplace else.

R: Good question. I think it's a person as inexperienced as you might expect to be given a G-2 job. Is that a reasonable way to see it?

E: It's more likely to be a repetitive position as opposed to , I mean, more likely to be an initial position as opposed to a repetitive.
Craig Cook: So it's kind of like their first assignment when they come out of G-2 school.

E: Yes.

R: We've asked him, with that in mind, to focus on those kinds of knowledge which he thinks would be terribly important for the guy to have and he's not likely to pick up elsewhere. So it's stuff that's sensitive, or controversial, or technology is advancing so fast it hasn't had time to get into the books, but it will again be Ennis's judgment about what's top of the line for this guy to know. Any questions on how we're positioning on this? Initially...

K: Question. Would the stuff he's not likely to pick up elsewhere include things like; this section of the book should be emphasized relative to this other section?

R: Well, I think that's fair game. It sounds like one of those items that if the doctrinal document has been well written somebody will have said "this is the most important part".

E: You've got to know the basics and the question is; how much does the basics encompass? That is a hard question to answer. You come up through a specialty, but at that point you've got to be broader that your specialty. Example; you will want to use the intelligence resources of the brigades, the aviation brigades, the maneuver brigades, the artillery. You don't control them, you've never served with them, you don't know other than a little bit in school enough about them, but you must know them because they are part of the resources that can assist in the collection of information. So you'll have your own corps knowledge but then you must have a larger which is hard to define.

R: Again, you'll be the judge. You have a limited amount of time to convey your wisdom, your sense of priority, what's near the top, and that is a reflection of what they're most likely to get wrong, so for example, if enemy order of battle is terrible important, but everybody knows that, then there's no point to give it precedence.

Sequencing: we'll have Ennis first give us any general advice, maybe 5 or 10 minutes that's not task specific, then pick out a particular subtask, and I think Ennis has picked the number one task that Freeman suggested, he gave a list, and we'll start off with the first one, and just use his judgment on what he would convey. It's important that the material that we get from Ennis

be able to go into some kind of holding bin that could be a written document, conceivably a computer program, or even a training program, that will exclude direct tutelage from the expert to the knowledge, so that's a vehicle that we're not including. Probably in this case it will be something that could appear in a document.

Then I will launch the more aimed elicitation with a couple of little ideas I have that represent my view of an interpretive and a generative approach and then throw it open for any tacks by any of the rest of you, (especially , I think, John and Marvin and Craig, but anybody) that takes advantage of their particular perspective. Don't worry about duplication. I mean the fact that the issue has already been covered when we answered another question isn't a reason not to try it here, for obvious reasons. So, if you'd like to start us off, Ennis, with your first broad and then narrower contribution.

J: Question. Before we begin, for the benefit of those who may not know it should there be an overview of the scenario that we'll be using?

R: Is that something that if you, for example, took 5 minutes, something useful could be got across? Why don't you try it, and if you can keep it to 5 minutes that would be ideal.

J: I probably could do that, I'm wondering if we'd be more interested to have General Whitehead do it , I mean, that might be a form of knowledge elicitation in and of itself.

2. *BROAD GUIDANCE*

R: Do you think? In that case, why don't you [Ennis] wait until you get to the point of being specific. Here, give your general comments and when it becomes focused on this [scenario], take five minutes off to set the scene.

E: I will try to not talk to everything. I see the problem for a new G-2 as one coming in prepared, through training, to the job, and then to adapt what he learned in training to a real live wartime situation and to very quickly find out where the previous things taught that he learned and experienced are wrong and what's right. So he is an inexperienced G-2, as opposed to a novice. So it's adapting training to the real situation and I think my notes cover that (1). There is more than knowledge involved, and one of the key notes here is that being a G-2 is not being a one man expert, but understanding how to use people (2). So there are some other functions he performs in addition to making assessments and judgments and that sort of thing.

If I were then telling the G-2 in this particular situation; "As I understand it the situation is laid out that the enemy has been attacking fairly successfully without too heavy losses, we have been delaying successfully to the west. During the night, the division commander pulled back a couple of units with the brigade headquarters so that he has a very small reserve, two brigades on line..." (3)

R: Excuse me. Ennis you might just want to take a moment to set the scene that it's a German defensive scenario...

E: This is a typical German scenario of the fifth corps area called the Fulda Gap area. It's used in all of the Army training to set the stage to examine issues and so it makes a very good one here. There is sort of a pro-forma Red force attacking which has a much larger capability than the defending Blue force. Of course, the purpose of the Blue force, in this case the 52 infantry division, is to defend successfully in its sector. As the G-2, I've learned first that on the Blue side there are two brigades on line, with most of the battalions. There is a small reserve with one brigade headquarters. The previous G-2 has said that the two attacking divisions have kind of slowed down, they've run out of supplies. I note that their strength is still very high. I note that a couple of regiments apparently have not been committed, so I challenge that. All that tells me is we don't know enough. There is a ninth, another large division, uncommitted, behind. The report is that it is stationary; that surprises me, because it's within artillery range, I wouldn't think they'd put a reserve sitting still, within artillery range, when they can move it fifteen kilometers back. So I wonder if it's not attacking this moment and we don't know it (4). I realize that reporting takes one to four hours to get to us at division level so what I'm learning at 0600 in the morning may be as old as two o'clock in the morning. So it is maybe no older than one hour but from the front line back to division does take time to report.

R: Excuse me, Ennis. Do I take it there are no broad messages that you'd want to be sure that the G-2 leaving Ft. Leavenworth has in his head? If your judgment is that you'd want to get into a specific instance and say, "if you're in a situation like this...", that's fine I just wanted to check...

E: I'm saying I would not accept what I've read in the intelligence summary as being very good. I'm just not certain. So when he comes in, do not accept the perceptions and assumptions of people who are new in wartime, that they've got it right.

R: So there's a general message that's prompted by this particular situation.

E: Yes. And this being a new wartime situation we're all new at it, we're going to our first combat and we probably don't have it right (5). So my first thought was when I saw the situation is with the new G-2 he's got to begin to make a new assessment to, either reinforce that what he has seen is correct, or to find out what is wrong. Then I try to turn that round into the priority intelligence requirements; which were basically: what's that division doing there, which could be; being committed right now and attacking? What's happening to the larger force in the rear of the seventh tank army which is within 50 kilometers? (knowing that doctrine is that they hold them back about a hundred km until they commit them as if actually in motion about to attack.

R: So the general point that you make out of this is don't take on trust the intelligence summary that you receive when you arrive there (5).

E: And the other point I'd make at this time is I think you're thinking in too narrow a time span. The G-2 should be out I would think 24 to 48 hours ahead. 48 may be too far, but 24 for sure, as opposed to looking at only what's happening right now which is really history, maybe 4 hours old. So I'm going to make my thinking to get ahead.

R: So you're advising him to recapitulate what's happened in the recent past.

E: And to project himself to get ahead of the power curve in estimating the enemy's situation (6). The one other point is ...I think that's enough for now.

R: No, make that point.

E: A perception is that there is a US corps and a German corps. There is a boundary between the two. Historically, they teach you to attack on boundaries and, what's more, attack on the boundaries between national forces because their coordination between the forces is less (7).... Their reaction to a penetration is to protect their own selves, so each side is liable to pull back on its flank and allow you to go on through. So I said that I would send somebody up to the 23rd panzer division very quickly, to have an eyeball assessment of what they think 's gonna happen (8); and make sure I understand what's happening up there, because the natural route of that seventh tank army is toward the boundary between the US corps and the German corps.

R: So you're mentioning a consideration that might lead you to second guess the intelligence summary that you received.

E: I'm trying to add to it. You're not second guessing; you're just not satisfied with the level of information that you have now. Note that I am also trying to get out in front. I'm not trying to worry about this battle, where it's going on, but what the larger forces can do which has a greater impact on our division (9).

R: Is there a general word of advice not specific to this scenario but that suggests to ... for the G-2? Is there something there that he can carry away (10)?

E: I would say you think further ahead than the current battle. And learn how to use all the intelligence collection resources that are available to you both directly under your control and not under your control. And recognize that all information that comes in is based on estimates or incomplete observations and that therefore you must be prepared to challenge it and go back some other way to get confirmation and yet you have a responsibility at the same time to hurry the information into the commander. So I guess the other thing that speed is more important than accuracy as long as you're there to make judgments on what he's hearing. So get out in front, have prompt reporting, and use all the resources that are available either directly or indirectly. It's a management task (11).

3. SPECIFIC INTELLIGENCE AREA: ASSESSING ENEMY MOVEMENTS

R: If that covers the generality of this much do you think as is top of the line, would you like now to get into the more specific task or...or whatever variant of it you think would be more helpful?

E: The task is the method for tasking specific subunits in an intelligence assets to locate enemy regimental, division and army command posts ... to

locate the headquarters of 128th Motorized Rifle Division, the 9th Tank Division and the 10th Combined Arms... (1)

R: Let's hold off the second part of that until you've had a chance to give whatever general comments you feel would be appropriate.

E: I think of that as being a specific task but not the task of the G-2. The G-2 is saying "I wanna know what those organizations are doing." A sub bit of information is where is the CP.

R: The CP?

E: The command post, excuse me. I would much rather know whether the ninth tank division is moving or stationery than I would to know where it's command post is. Now if its command post turns out to be fifty kilometers to the rear then we've got this data wrong: that division is within fifteen kilometers of the front line (2). But I assume we have enough information to know that the division is where it is, so finding the command post is primarily for shooting at it with artillery and that's a subtask. I'm more interested to know what they're going to do. So my surveillance which I would put out: I would ask corps to give me the mohawk (which is an aircraft which can see moving vehicles) I would, of course, have it concentrate on one, looking in the ninth tank division area to see if there's much movement. If you get a lot of vehicle movement then you can perhaps come to the conclusion that yes, a division-size element is moving and secondarily look deep toward the tank army to see if it's moving or not rather than narrowing it down. I'm more interested in what the organization is doing as a whole, as opposed to the location of a command post. The command post helps to tell me where it is but that's not a major point. What intelligence assets would you use, the primary ones that you would have to use, and this is what a G-2 should know when he arrives. You should ask for the corps surveillance aircraft to watch in those areas. That's the mohawk; they have airborne radar on board. He would ask his own ground communication asset, who detects signals of radar (and knowing that a division has certain kinds of radars in it) if he can detect signals in this area, which would be tied to either the artillery or the air defense system of that division. It would help him to tell that the division is there. I of course would count on a communications intercept aircraft guardrail, and the ground sites which would be listening, not only for what's going on in the units or in contact, but (particularly guardrail and corps) you might ask what they can hear from there (3).

R: Is it helpful to comment on what the underlying reasons for those suggestions would be (4)?

E: The threat of the ninth tank division about to assault you.

R: So you want to know whether it is or not?

E: I'm trying to use all these collectors to find out what it's doing. Which I think is a more important question than just the location of the command post.

R: So in terms of primary information requirement, what they're up to you give higher priority to where are they?

E: Yes.

R: Ennis, is that in your mind's eye tied to any action implications for us if you find it one way or another?

E: Yes, if they're crossing their line of departure in the attack right at this moment, then maybe all three courses of action don't make sense; because I'm not sure the division commander can implement a course of action of putting a third brigade headquarters in on line, while a major combat's going on and rearrange the battalions in contact. So all the courses of action may be unfeasible. It wasn't clear to me when they were to be implemented, but they may be unfeasible if or impractical if the ninth tank division is actually attacking at this moment. We may know in thirty minutes which avenue he's on so I'm trying to get further ahead.

R: As far as a trainee G-2 is concerned, you have any comments that would help him replicate the kind of reasoning that you've produced when he doesn't have you at his elbow (5)?

E: The rule of thumb is what is the most serious threat to the division and to the accomplishment of the division mission? We believe we're able to contain the divisions which are now attacking and in contact. We don't know if we can handle the reserve division, the ninth tank division, and it is only 12 to 15 kilometers away. If it is in fact sitting there, it is within one hour or less of moving, only one hour. Behind it is a much larger force, five times our strength, or four times our strength, which can attack within, if it continues its movement without delay, it could attack in 4 to 8 hours. So those are the greatest threats, because they can destroy the division or, more likely, cause the division to fail in its defensive mission.

R: And has some clear implication for what we should do to head it off. Is that true?

E: If we know what they're going to do and where they are then the division commander, the earlier I can tell him that I have confidence in what I think is going to happen the earlier he can begin to adjust his forces to handle it. Also I should be thinking like the next higher commander because he has a reserve which he can give to me, to my commander, and if I think I've got a problem and if I think I'm going to get the major attack then I can get a commitment of that reserve brigade and I can set up my defenses so as to take advantage of that and make my capability of either defending or counter-attacking more viable. And remember to get that brigade there and to get these forces up I need to 2 to 8 hours and if I don't tell until the last minute he can't use them.

R: Time out for a procedural question. Is it your feeling that the best way to get this kind of skill, exercise of judgment into the G-2's head is to give him a concrete for-instance, where you explain why it is; as opposed to giving general precepts of the type that appear in doctrinal documents (6)?

E: You've got to have the precepts, you've got to have what I call the basic set of knowledge: training, education...

R: And they have that.

E: And you've got to teach that first. Then of course I have to comment on the Army's system. What they do now is practice it in Leavenworth, practice it in the field in command post exercises or field training exercises. As a more junior member of the staff you watch the more senior member of the staff do his thing, and you do some subpiece of that for him. So through your training and your experience at a lower level you then hopefully have the basics to do a good job when your day comes to be the G-2.

R: Another procedural question. Having got the for-instance out, do you think it's helpful to make a general comment or just let the for-instance tell its own story without particular interpretation? Would you care to comment one way or the other?

E: I think the general comment is useful. Because I think the for-instance can be misinterpreted or has many,there may be many general comments which apply but in my mind there'll be certain ones which will appear to me to be more important.

CC: Are we in a situation where you are briefing the new G-2 and you're going to disappear and so he'd better ask everything he needs to know right now. Or is he going to take some action about which then he can come to you and say, "Here's what I've done, here's the result, now what should I do next?" or "How should I interpret what I've seen so far?" (7)

E: The first. This could be a real-life example. If he could be at the corps headquarters now and the corps G-2 says "You're going down to the 52nd Division and here's what the situation is and here's what their latest intelligence summary says. Things are a little different from peacetime and, young fella, here's my advice to you."

CC: OK. You made a statement that said earlier that you shouldn't believe the intelligence summaries that you receive out of hand, that you ought to go back and re-collect some of that intelligence for your own consideration. My question to you is: "how do I decide which sources to believe? How do I even know that those troops are out there?" You seem to take for granted that they were really there, but you're not quite sure whether they're moving, or something. Is there some level at which you're willing to say: "yes, we believe this part;" but then there's another level at which you're saying, "don't believe that summary," or, "don't believe that piece of intelligence." How do you decide which to believe and which not (8)?

E: I would say do not not believe it. I think you never know enough to be satisfied. The intelligence summary is always an estimate, based on limited information, and people are making judgments on it. You in fact will begin to make those judgments yourself, and could some days be very accurate and some days not, based on limited information.

Now among intelligence collection resources (again part of the basic knowledge), there's not much that can see beyond a couple of kilometers or, to use the standard thing, five kilometers. Because there aren't very many collection means which will provide beyond that; so in looking at those two deeper forces [7th and 9th] that I'm worried about, you immediately have to

narrow yours to the assets which can look deepest. Some of them are at a higher level - I mentioned the corps mohawks. So you're going to call the corps and say "I need your help right now because that doesn't make sense that they be sitting that close, they must be moving. What are you getting from the surveillance aircraft?" (9)

KL: I'd like to restate Craig's question. You looked at the intelligence summary and said "Well, they say that the ninth division is out there and they say that the 7th army is back beyond. They appear to be assuming that they're just sitting there. I wouldn't assume that. I would collect information and try to find out whether they're just sitting there or whether they're moving." But you didn't say, "Gee, they said the ninth tank division was here. Maybe it's really not here. Maybe it's somewhere else." So in other words there were pieces of the intelligence information that you more or less took at face value although of course that can be uncertain too but there were certain pieces that you decided to collect information. How did you make that judgment?

E: You're right. I made a judgment, rightly or wrongly, that they had located the ninth tank division. In the intelligence business there are some sources that are better than others. If the source of that, and I would ask, "How do they know that?" and I should ask, "How do you know that?" If I was comfortable with what the sources were, then I would more likely .... A good question is whether or not it's there at all. That's a fair question, and I probably made a hasty assumption, assuming it was there, accepting the intelligence summary. Normally you don't put something in that close unless you've had a pretty good indication (10).

CC: Does that mean that certain intelligence pieces of information are hard data, that is visual confirmation or ... direct, confirmation and others are inferred things based on assumptions, based upon piecing together other things. Are you saying that you would rely upon the hard data things and question the assumption kinds of things?

E: Yes. If you'd heard over the radio somebody talking and your direction finding put it in that area and you heard elements of talking which appeared to be in the ninth tank division then you would probably give that a high probability of that being correct. If you also then had a photo mission over there which showed lots of vehicles on the move including artillery and tanks and VMPs, that would tell you there'd be a million... (11)

R: VMPs?

E: That's armored personnel carriers. That would tell you there are a mix of forces which tend to be in a division. If they are more than what you would find as part of the two divisions, if it appeared to be more than just the reserves of the two divisions in contact, then that might lead you to believe yes, there is a division, part of a division there or more than a division or something big there. So you would piece it together. I would accept at face value there was some sort of division in that area. That may be wrong.

KL: This may be beating a dead horse, but I'd like to push this just a little bit further. When you looked at the intelligence summary you, immediately said, it sounds to me like you were saying, to yourself, "If they're saying

the ninth tank division is there, they must have this kind of data and that kind of data and the other kind of data, or it is likely to have come from these kinds of data, which are good." And so when you look at intelligence summaries whether, or not they tell you where they got the data, you have hypotheses as to where they got the data and whether they're likely to be good or bad. Is there any kind of guidance that you could give to the G-2?

E: He should go back and check those. We have concentrated the subject on what appeared to be the greatest threats to the division so there's a lot of other questions out there which would have all the same implications. But see at least what I'm doing (12) - I accept it perhaps too hastily. I don't know but if I ask for the evidence which said it was there, and felt comfortable that there was a ninth division somewhere in this area, then I want to know most importantly what it's going to do. That's the part that I'm worried about because again it would have the greatest impact on our own forces. I'm driven by what will have the greatest impact on our own forces. And the other one we haven't mentioned of course are nuclear weapons (13)...

R: Is it generally true that in a broad class of situations it's enemy intent and movement which is the dominant concern; or does it just happen to be the dominant concern in this particular scenario for reasons that are specific to it (14)?

E: Enemy intent and capability are the dominant concerns, because they have the capability of attacking and we're defending. The problem for us is, "can we conduct a successful defense?" What I'm worried about is will this give them a favorable force ratio which would permit them to advance more rapidly than they have in the past and therefore penetrate our defense and cause us to fail in our mission.

R: With a clear action implication for us we've concluded?

E: If I'm able to tell the commander that they're sitting there, not moving and don't appear to be moving, that gives him more freedom of action than if I report to him that there actually seem to be moving forward and we can expect contact in the next thirty minutes to an hour. So it has an impact on his choice of courses of action (11).

R: To look for a contrairy case, might it sometimes be that it's obvious what enemy intent and action is and therefore does not deserve high priority in additional intelligence gathering?

E: You noted that I didn't put on a high priority the activities of the two divisions which are now attacking. And they are a threat. I think they're more of a threat than the intelligence summary described but they are less of a threat than that, so I have sort of not put the priority on what they're doing. Again, part of the education process. Those are brigade fights with the units in contact. I'm more interested in their reserves and the reserves behind them. The brigades are interested in what they're in contact with or what they're about to be in contact with. So my problem is the larger one of the division. The brigade S2 is running the same problem but at a lower level.

R: Time out for a procedural question. What we're doing now is something that one can imagine taking place in a classroom at Ft. Leavenworth.

E: Yes.

R: It sounds like a candidate way of eliciting information is actually to replicate a meeting like this, in the context of a scenario with a seasoned expert, making exactly the kinds of comments you are and responding to the kinds of questions you're getting from the floor (16). Any comment on that as being a promising...

E: Yes. The only thing you might want to do is to [add to] the elicitation experts, to add in, very selectively, a knowledge expert who can pick up on something that the subject misses - that you all might not pick up - but I think this is an excellent method.

4. OPEN DISCUSSION

R: The meeting is now open for anybody to raise questions, such as Craig and Kathy have; not yet testing out any more systematic procedures, but just at a common sense level, such as one might produce in a class in a training class.

CC: How important is it to know what actions the red forces could take; that is, how are they limited by geography, weather, resources, ammunition, whatever, and does one sort those into some reasonable number, five possible actions that they could take or are there *hundreds* that they might do? (1)

E: Yes, you must sort into courses of action. At least it's normally done to narrow them down to a few that you can manage. There are three general courses of action here, and then each general course has its own [subactions]. For example the divisions on line, which are attacking and can continue to attack the way they are and they do it would have separate courses. The ninth tank division could be committed in the attack and there are several ways that it could be done. Or the the seventh tank army could come marching along up and then it could attack in the north [and in] the south in a completely different corps area. So that's the way I'm looking at it. There are several situations, each of which could lead to a number of courses of action.

CC: Ok. Is it possible that there are other courses that you're not aware of behind your back, coming up from some other direction. Is it wise to concentrate on everything, all your resources on this particular problem at hand; or maybe to save some against a surprise attack?

E: You're always worried about the things you don't know. First, commenting on the red conventional forces. There are enough of them out there which you've got information on, that you would feel fairly comfortable that you have a pretty good knowledge of the general forces. What you don't know are use of nuclear weapons, what you don't know is whether he has any sort of deep attack with airborne forces, which could interrupt your rear and those worry you. As the G-2 you try and get some sensing of the level of that threat, because, if you have a threat in the rear, that means the division commander has to put forces in the rear, which makes him weaker up front. So there is a those are important, and you must make judgments on them.

R: Time out for a procedural question. As I hear you, most of the suggestions you're coming up with are not related directly to what use you should make of the information. It's focusing on, "this is information that we would like." My question is: is this because the way you think about it is: you directly perceive that a kind of information like "what's the enemy doing" is important or is it natural for you to think "it's important because it will have a critical impact on what I will do thereafter?"

E: I'm thinking in terms of the indicators that I can receive through the intelligence means. I must then make judgment. For example, with the ninth tank division, if I can see movement of three large columns of a hundred vehicles, each moving out of that area, my judgment will be they are about to attack. That will be the estimate. What I need are the indicators from which I can make the judgments, so my conversation is sort of concentrated on the indicators. If that force in the rear, the seventh tank army continues to march westward, then it tells me if it's getting closer and closer to our forces that means it has probably finished its attack preparations and is about to attack. Looking also at the terrain gives me an idea of which is the most likely direction in which it will attack (2).

R: Presumably, the reason why you think that information is important is because if you thought about it you'd say, "hey, we could make a costly mistake if we guessed wrong." My question is whether thinking about the costly mistakes you might make is in the forefront of your mind but you've chosen not ton mention it, or whether you get a direct sense for what's important information and it's only implicitly that you're figuring it out why it is that it's important. If you agree that the reason one information might be more important ... than another is that it may save me making a costly error in terms of subsequent action (3).

E: No question about it, this is a two-sided game. I am worried about those things which appear to be the greatest threat to the division mission. Remember it comes back to accomplish the mission. In order for the commander to do a good job in doing the mission, he needs to know what the enemy is going to do. For example, ... threats to the division first which have the greatest impact on a mission. Then technically I'm trying to give him as good an information, as early as possible, so he'll have more time to figure out the counters. Then I have to keep asking myself "Is what I told him four hours ago based on the limited information, my estimate [now]. I've got to keep challenging my own estimate (4). So I may go back and say, "what did you really see out there?"

For example, when I look at that picture [point to map]. One final comment. It shows four regiments. That means, in the lexicon of our training, that they have identified all four regiments, not the ninth division just as a symbol, and that's tremendous information. Now, if they're not sure, they'll put a question mark behind the symbol. Or, if they weren't sure, they would just have the division symbol. So, looking at the map, the G-2 must have very good in formation that the ninth tank division is there, and very good information that it has those four regiments in it, and very good information that they are generally where they are, so I've accepted that. But I would go back and want to know how he got such good information. So the final point

there is: some training implied here, and there is a standard procedure for showing things on maps. And that's part of my estimate.

Th: I have a question. A lot of what seems to be going on when you come up with strategy for data collection is role playing. You're playing the role, putting yourself in the shoes of the attacking commander, and putting yourself in the position of you're coming through and what he needs to know and how ...in order to get ahead of the game in terms of information. How much of what you have to do is that role playing, and how much of it goes back to looking at what you know about various intelligence sources, to look at reliability? Do you spend a lot of your time role playing?

E: In theory I have completed my training session in the Army. I have ten years experience, let's say. I am now living off that training and education. I know what a mohawk aircraft can do. I can know what a ground communications collection system can do. I know what a radar .... can do. So I now have moved up to a higher level of trying to put it all together (4).

?: How do you know how to play the roles of your commander and the other commanders?

E: I'm probably not playing the role of my commander, because he probably asked me these questions. It could be, I hope I anticipated, he may have already asked them. On the other side again, based on my training, I have gone through the school systems and I have learned what the Soviet doctrine is, have learned how they're organized. And what I am trying to do now, so I am role-playing what I learned in peacetime. What I should be sensitive to is how much of that is wrong. Or what is different. But the doctrine in peacetime tells me that they keep their reserves farther back outside of artillery range, outside of surveillance range and then they move them forward very quickly into the attack. This doesn't fit that model so I'm challenging the sitting still. I think it must be attacking. I could be wrong, but I did put it against the model of what I learned about the doctrine.

CC: Now does part of what you're telling the new G-2 include an assessment of what the commander prefers, what style of intelligence information he likes, what his conservative versus aggressive kind of behavior is, what is a .... story to tell him versus a story that's not useful? Is it commander-specific as well as just the ... (5)?

E: I probably have a commander model in my head I don't recognize, I can't identify right now. I do know that some commanders will claim they are better G-2s than the G-2 which means that he will play a very active ... in saying "why do you know this? Do this, do that." He will be a very strong leader ... Other division commanders may be more passive.

R: Is the expert's contribution where to put the priorities? Is it, alternatively, that he'll be in a better position to implement the search for a particular type of information? Is it a blend of the two or something different?

E: I would think with his training everybody always thinks they can give good advice. My perception was to give him three things (6): one, tell him to concentrate on the high priority things, in other words prioritize. You can

be caught up in a division command post or corps command post, you can be caught up in the terrible details. So I guess one of the things is to keep your eye on the high priority things. Look in great depth and detail to see if the people who are giving the information know what they're doing. But that's a spot check. Keep your eye on the high priority.

The second point again is to learn how to use all of the resources available to you which are directly available or indirectly and take full advantage of them. In other words, get 110% out of 100% of ...

R: Let me now sharpen the question a little bit. Do you have any concerns that ... the G-2 that only had the standard training and read the standard documents will have a misapprehension? For example, are you responding to a risk that he may just go through the list of informations routinely called for, without taking the particulars of this situation into account. So I'm asking you whether you see any important gaps in your typical G-2 as he comes out of Ft. Leavenworth that your comments may help to plug? Does he need the information we're eliciting or he probably could manage just fine without you're ministrations (7)?

E: I don't know the answer to that question. I really don't.

R: It prompts a more general question, really underlying the whole project, which is: how important is it to elicit knowledge that goes beyond what people acquire anyway? And if you could comment on it, focus on this case, if you find that convenient?

E: I intuitively believe that there is. I cannot factually assure you that it is true.

R: Is there anything for example that you'd be concerned the G-2 might do if you hadn't got to him?

E: I start from a baseline that all everyone only knows a portion of their job. No one ever knows it fully and in wartime you're experiencing it for the first time. I have watched people perform in combat and those who receive good training and education, not just from the school system, but models set by other people, do better in combat quite often than those who have not. So I'm saying that the experience based on that sort of observation, an experienced G-2 or an experienced expert could provide some value added to the training which it provided in the school system. As an intuitive statement..

Th: Question. One of the things that you did when you went through instructing the trainee G-2 besides mentioning prioritizing collection and using all resources was at least I thought you were doing this, identifying sources of uncertainty and identifying places where the patterns you might expect or recognize from your training might be wrong. So one of the other things I thought I saw going on was an emphasis on sources of uncertainty that you might not anticipate from your training, that the real world may have uncertainties and unexpected things (8).

E: Yeah. From the training I find that the Soviet division is in a strange location to be sitting. So I assume it is attacking. But I've also got to

find out whether my perceptions or the training is right. I'll also learn whether it's right or not, when I find out the answer to the question.

Th: Question again. Is it important for a G-2 to realize that their training may be flawed and to be aware of that at all times? Is that something else you're trying to teach them, be aware that your training has limited applications in this real battle.

E: I guess I would use the term the training is incomplete. It could well be flawed. It's surely incomplete.

M: We have a case here of one type of knowledge, a knowledge of doctrine conflicting with, presumably, evidence, intelligence summary suggested, whoever prepared it, that this division was included [?]. And you're suggesting let's find out if it's true. I'm interested in two things. One is, how you weigh these competing sources. In other words, what if we go back and check, and still aren't real sure? The second part of my question has to do with the fact that if they were moving that would have serious consequences. What if it were reversed and the estimate here was that they were moving and doctrine suggested they weren't? In other words, the summary that you read when you came into the job said, "yeah, they're attacking," and for some reason, doctrine suggested to you that's very unlikely. Would you then not bother because the estimate was suggesting that situation and your prior knowledge suggests the situation might be better than the estimate rather than worse ... Would you be equally enthusiastic to employ intelligence resources to double check the estimate if they were going with the worst case? Is it because they're going with the best case that you're more motivated to double-check?

E: The reason I had concentrated on those two forces is because maybe, as a G-2, I'm taking the worst case. What could do the most damage to my division and its mission? And those two forces can do the most damage. And, since it the one division is only ten kilometers away, I need to know what it is doing. I'll be very happy if he's moving away from me; I'll be fairly happy if he's stationery; I'll be more agitated if he's moving forward, because the commander will be agitated. So again, regardless of what it's doing, it is a significant threat to the division mission. So remember in my job, I'm taking everything from the division mission. Which gets us back in that old short term [priority] which is: mission, enemy situation, terrain, own troops and time. The first one is mission (9).

M: Let me put a question specifically. What if you instruct the mohawks to look, but because of cloud cover, or whatever, the results are inconclusive?

E: They get shot down.

M: Then what goes into your estimate?

E: In my list of collectors, I've got as many as ... For example, this would be very high priority, both to the division and to the corps, to have an Air Force give this coverage also. So you would probably not only use your own division intelligence collection resources that could reach out there, and ask for the corps to give you coverage, but in this case, because they are such an important threat, you would ask for Air Force reconnaissance.

M: Let's assume that if there were no [*special U.S. action?*], they would be here in a half-hour, and there's nobody that can really verify it in that time. You have to give some input to your commander right now (10).

E: There are some other things that a G-2 would do. You would ask the brigades if they had any signs of reinforcements (11). You would ask the aviation brigade, which has a lot of helicopters, are they seeing any sort of movement back there visually; because if it's a clear day they may be able to see five, six or seven kilometers deep. You would ask the artillery if their airborne observers are seeing anything. You would go to your signals collection managers and see if they're getting any new signals and locations of signals along the march. You would probably put your EH60 helicopters up, which can collect radar signals, to see if, as they moved on the march and had their air defense with them, are their air defense radars moving along there? All these would be indicators that maybe something [is going on]. You're worried enough about that, because it is a threat. You would like to find out for sure what it's doing and you would concentrate your collection of resources, those that can see over the hills, to try and give you more information.

CC: To follow up Marvin's question, if you cannot determine conclusively what it is that they're doing, how do you express this uncertainty back to the commander, to kind of convey that you haven't been able to reach a conclusive choice, but he needs to take some action soon anyway?

E: My conclusion to the commander would be, if 2 or 3 hours went by and I had't gotten some feedback from the collectors that I've asked, or the people who are analyzing collection to look for any signs that make sense, I'd say my conclusion would be that they're stationary, because I have seen no indications of moving. And I believe I could see indications of moving.

CC: So you would draw a conclusion, you would not say, "Boss, I don't know what the answer is. All of our sources are down. We just can't tell." You would draw some kind of conclusion based on whatever evidence you have arrived at.

E: And I would tell him what that evidence was. We have seen no evidence of heavy movements to the west of that area. We have seen no new signals of new communications net which indicate a force moving up. We have seen no radar signals which would indicate that the sands [?] are moving forward. We have seen no new artillery in position firing from our artillery observers. I would give him all the negatives. So the best I can tell him is the ninth tank division remains there, hopefully, or I begin to see evidence that it's not there.

R: Can you give a measure of uncertainty?

E: You can give a measure of uncertainty.

5. STRUCTURED ELICITATION: STEP-THROUGH SIMULATION

R: Even though we clearly have not exhausted what Ennis has to say that's useful, I think now's the time for us to try out some more structured

approaches - the kind of things that might not come out of a classroom bull session. I have two in mind, but I don't want to push those ahead of any other systematic approaches anybody else wants to try.

The first one I'd like to try is what I call step-through simulation which is very similar to traditional war gaming (1). Normally you'd have perhaps several people playing different parts of it. Today we're going to try and just pick your brains, since that's the name of this particular game. What I'd ask you to do, in the same context, is to draw out a sequence of events from your imagination. Tell us if that's too much of a challenge but if you wouldn't mind trying, please follow two different strands. One is the world unfolding as the G-2 sees it, and that includes what the environment is doing, weather, what the enemy is doing, and what your colleagues are doing. Those ones you can't control. And then the other strand is: what you would be thinking about as a G-2 and in particular what you would do as this imaginary scenario unfolds. It's going to be probably a little bit difficult for you to both play the world and play the G-2 but we don't have two characters. But you might like to comment on the contamination - effect not just the burden effect, but the contamination effect of having to play both sides of that. Is that reasonable, to ask you to take one step at a time, starting at , well, 0600 on the 19th or a different more convenient point in time?

Let me give you a little prompt if you find this helpful, but I don't want to steer you when you have an impetus of your own. If you could take the position that the commander of the division is basically intent on one of the courses of action, say, course of action 2. However, we understand that, as events unfold the commander may change his mind. You may start off in that direction. Assume that you know only what the G-2 might learn. He, of course, wouldn't learn for sure what the enemy's doing. More realistically, you would not make any assumptions that the G-2 wouldn't know. It's probably best not to make any assumptions that we know something (from the scenario-writer) that the G-2 wouldn't know.

J: General, let me interject, why don't we go with course of action 3, the balanced thin line that you liked with the large reserve maybe forward, as you would have placed it.

E: Would you do one other thing, would you give me a time frame or do you want me to invent it, when it's supposed to be implemented?

R: Let's try this on for size: we take the scenario as described here, which as I understand it is that you're at 0600 and you've got about 4 hours to decide on a course of action. Unless you have a different suggestion, suppose the 4 hours is over, so we're at 1000 and the commander has decided on, as John suggests, course of action 3, and now the camera's rolling.

E: Well, let me ask one more question. He decided on course of action 3 at 1000 hours, and when is it to be implemented? Is it during that same daylight hours or is it to be done the next night or ... let's make it as soon as possible.

R: I think we should use your judgment, whatever seems a plausible, most likely sequence. Whatever your imagination throws at you as being a plausible

unfolding of the scenario. And don't worry about it's being the most plausible but just a plausible one.

E: The larger situation which I am imagining is that at 10:00 the division commander has set down the new course of action 3 and will implement it now. Basically what that does, from the maneuver forces side, is that he will begin to withdraw some of the battalion task forces, which are now forward, and to move the brigade, the small brigade which is in the rear, to another location and to build that reserve up larger. So he will continue to fight with 2 brigades forward, the same organization he had; but he will take away some of their forces to build a bigger reserve, a fairly logical sequence of events. He's going to do it now during daylight hours, because he's assumed that he can move on the road without too much harassment from the air and that he can extract those battalions which are forward and get them out of contact. It's doable.

R: Is there anything that as G-2, you would put in motion right away?

E: Two time frames. It is too late to do much right now for something which is going to happen starting now. I come back to my original point, I've gotta try and get 12 to 24 hours out ahead. Having said that, I still must do everything possible to see if there is going to be a major threat which will prevent that course of action from being carried out. The course of action being to thin out the front and create a stronger reserve.

R: So at the general level, all your antennae are out to see if there's any counter-indications for your primary hypothesis (2).

E: The system is slow enough in operating that I cannot say, "I want you to fly out and do this and give me an answer in the next ten minutes." So you have to live within the time scale of which things can be done. But at the same time I would probably energize the system by some direct calls to people who are doing the collection and say "Look, be particularly aware of what the ninth tank division is doing."

J: That's these guys here [pointing at map].

E: Yes.

J: This is an overview of what the state of defense is, it's not the way it's aligned now, roughly how the enemy is in line.

E: As well as the course [?] of the forces that are in contact.

J: Right. These units are bigger than these units though. I mean, even though they're depicted as the same, so bear that in mind as well. This is the ninth that General Whitehead's talking about.

E: I would also, of course, give him what the force ratios now along the front between red and blue. I would have given him that (3).

R: That's in the intelligence summary.

E: I would be trying to sensitize a little more the collection and surveillance plan that's already in motion. In other words you, there are only a few things that you could change at this late date and generally they're aircraft-related, that could help you any more than you're now being helped by the collection plan you have. But you would sensitize the people who analyze data to give you the indicators, as quickly as they can, of any change; and you would sensitize some major subordinates that you don't have any control over, the brigades, division artillery, etc. So that this is going to be beyond a watch-out [?], because this is going to be a sensitive period while you're withdrawing some forces.

R: In tracing the next step, could you let us know what you think of importance *might* happen, and then pick one of them and assume that it *does* happen.
What's the next surprise or interesting piece of information that might affect what you, the G-2, do?

E: There are several courses of action the enemy can have. One is that he could continue his attack with the forces he now has in contact or with a portion of the forces he now has in contact.

R: And you'd learn about it?

E: And we would feel that all the time. The front line units would report that they're under attack, they would indicate how many losses they're receiving, they would indicate how much the enemy [is moving?] there, whether they're stopping ...

R: So you've got a changing sense of what they're up to.

E: Yes. Of course, another course that could be happening is the ninth tank division could in fact be committed in the attack through one of those divisions.

R: And again you'd learn of it.

E: You would either learn of it, as it was moving forward, or you would learn of it when, in the worst case, they came into contact and you captured somebody from the ninth tank division in late afternoon and found out they'd been in combat all day. You get fired at that point.

R: If that's reasonably likely, (and I'd like you to limit yourself to a pass through possible histories that are reasonably likely) do you want to assume that it happened? Or is that really an outlier of something that's not on the most likely track. What's the next thing you think you might learn?

E: Probably, if a division was moving forward, you would get some indication. Remember it has a thousand vehicles in it or something of that order, 750 to 1000 vehicles. So you ought to learn. It has lots of radios, it has all sorts of other signatures. You should get some indication that it's moving.

R: Do you want to assume that you do get that indication?

E: And you probably would by maybe 10:30 in the morning, if our scenario is that that's what happened: they are attacking ...

R: So within half an hour ...

E: Let's say they had attacked actually at 8:00, or rather at 10:00. By 10:30 or 11 you would have some indication of a heavier attack somewhere. You would also know they were moving forward. You would then probably arrive at the judgment that the ninth tank division is probably attacking us in a specific area.

R: OK. Do you want to pick an area?

E: Make it in the center, sort of on the boundary of the two brigades, and..

R: Has it passed through the first echelon of the enemy?

E: It's passing through right now. That could take 1 to 20 hours. If it succeeds in making a good penetration quickly, it would pass through very quickly. If in fact you stop them, then they would be intermingled with some first echelon. So that's why I say I'm uncertain. What you'd be trying to find out was whether or not, how much damage you've been doing to them, where their main effort is.

?: I have a question. By first echelon you mean first echelon of the division, right?

E: Those regiments or divisions which were in contact already and fighting.

?: You're thinking of the red first echelon.

E: And the first echelon here is those two divisions which have been fighting in contact all of last night and the day before. The second echelon division is that ninth tank division, which we now find is attacking ...

R: What are they doing that we learn about?

E: We saw them moving and one of the brigades has reported heavy attack. Heavy artillery fire, air strikes in support of it, on one or two battalions as opposed to all the way across the front, with lesser fires on the other. The key there for them is to pick out where the main effort is. They may have things falling on all across the front, but where they want to find out is where the heaviest attack is. And they would be beginning to sense that.

R: Is there any chance worth thinking about that they would try to fool us? To produce preparatory fire power in the wrong place in order to make us think the attack's going to come through there. Is that a possibility worth thinking about in your scenario? I'm looking at the case where what's happening is different from what we think.

E: That is very likely to happen in a set piece attack, where the lines have been stabilized for some time. It is less likely to happen here, because they've really been moving forward all the time. So they haven't stopped, gone through the planning sequence of a special plan which would have that

deception; in it though they could, they still could. So that's possible, but I would say here less likely. Again they've got a supply situation, say in artillery ammunitions, so you may want to give what limited supplies you have priority to the forces who are conducting the attack.

R: But that's not a G-2 decision, that's a commander's decision, isn't it?

E: The G-2's decision is whether or not artillery fire over on the right flank is the part of a deception or not, and it is the G-2's responsibility to try and interpret what that means.

R: In your dream, do you want to assume that that does or doesn't happen, and only say "yes," if it's somewhat plausible.

E: I would say "yes," but let me say it in a slightly different context. Everybody will be given the order to attack, the breakthrough force will have more artillery, more weapons ...

R: This is the enemy?

E: The enemy, yes. Everywhere along the front they will be given the order to carry out secondary attacks. The primary attack, let's say, is in the center here. It will have more artillery with it, it will have more combat vehicles in the physical attack, and so the secondary attacks can confuse you. One, confuse you as to where the main attack is for a while; and the secondly, it's used to hold your forces in place so you don't use them as part of your reserve. So that will happen, but if they begin to make a penetration of your lines, you should know pretty soon where the main attacks are, or at least where the successful attacks are.

R: So what are you positing in your dream does happen?

E: That's right there would be secondary attacks, yeah, O.K.

R: There are secondary attacks, and we know that they're secondary attacks.

E: At least the only penetration is in one area and therefore we assume, - from the sightings, radio contact, rate of fire and everything, and the gravity of the situation, - that that's the main attack.

R: And we're confident that we're right.

E: You would want to pin down, again, the order of battle, how many regiments are in it, or how may divisions are in it? You would like to make sure that you're not being fooled and it's only a single regiment, and actually the rest of the division is about to attack from a different angle 6 hours later. In other words, premature diminishing of your reserves.

R: What would you do, if anything, to address that possibility?

E: As part of the standard operating procedure, you'd be trying to find out who's in that attack, the order of battle, and ...

R: And you'd do that with your CEWI?

E: Well you'd hope very hard that the defense would take prisoners, and you'd get their unit identification. You'd hope to hear on the radio nets, at least the number of nets that are up. You may not hear anything that you can get information from. You would hope that if you picked out certain kinds of artillery battalions that, by George, that's more of those battalions here than were here before, so that must be a new division, main attack. You'd be looking for all the small signals and pieces of information that would help you make a conclusion "By George, the whole Red division is in that attack." An then the deeper the penetration would get, the more confidence you would have that it is a major attack (4).

R: In the process of keeping your eyes open for these developments, would you take any non-obvious initiative, for example, in marshalling your collection resources, or would they just do their normal thing and the word will come back without your giving any special, non-obvious instructions?

E: Some of your collection resources are with the brigades, and the question is whether you would take them away from them or not. If, in the initial penetration, some of those were destroyed, you would make some adjustments just to make up for lost forces so that you kept majority of resources on the priority problem.

R: But this would be a maintaining decision rather than a shift ...

E: Then remember now, I have concentrated on the ninth tank division for some time, so what I'm really asking them to do is a continuation of the concentration of the effort. I guessed right in this case, so I'm really continuing the effort to know more about the location and activities of the ninth tank division, so I would tune it a little bit.

R: What I'm looking for is places where a poor G-2 might make a mistake. So we're identifying places where your decision is a non-trivial one, and therefore there's something to be learnt.

E: I think rather than saying he would make a poor decision, I think it would be his ability to use all the resources available to him and adjust them in the optimal way, some of which he controls, some of which he doesn't, and to pull the information out of the system and to adapt the system to do a better job, as opposed to being poor or good.

R: Can you give an example here of what you might be faced with, and what decision you would make in the light of it, so we get an example.

E: You might ask for some of the aviation brigades scout helicopter resources to be made available for you, to help you determine the size of the penetration. You might talk to the division artillery commander, to make sure he's concentrating his field artillery and airborne observers on that. Remember, he will also be doing that with his forces. You might ask that addition surveillance resources be made available from corps from their ...

R: I'm assuming that all these mights do occurs; in other words, they're in your dream.

E: Yes, they're in my dream. Let's say, I'm now getting into the G-3's business, but I would get to the G-3, and we may want to establish a surveillance line, or a reconnaissance and security line, somewhere outside the penetration, but where we think the penetration is going.

R: This is an aircraft surveillance line, or a radar ...?

E: It would probably be the reconnaissance squadron. It has both a good observation capability from the ground and air, and he also has a fighting capability. So the G-3 would be interested in establishing some sort of a delaying position, and I would be interested in their ability to observe and report what's going on.

R: And this is part of your own CEWI battalion?

E: This is not part of the the CEWI battalion. In other words, I would control it if they maneuver for it, which belongs to the G-3, which is in reserve. And I would say maybe we can get some of their [resources?], since they're in reserve, lets use their air cavalry squadron forward to do some reconnaissance rather than having them sit back there in reserve.

R: Is there some chance that the G-3, for reasons other than intel, might not go along with it?

E: Very likely. Suppose in the last three days they've lost half their helicopters, and he knows he's going to have to use them to fight with, and he knows he needs a scout helicopter with every attack aircraft. So he doesn't want to let the scouts move forward and lose some more of them, so for conservation of resources, or maintenance problems, or flying hours (our pilots have been flying 15 hours a day), or any number of reasons, he may not choose to do that.

R: Do you want to assume that's happened?

E: Let's assume that's happened.

R: Incidentally, if anybody else gets some ideas or questions to ask about this unfolding scenario, please do.

K: Just one interjection; that we might want to consider not just the situation where Ennis get it right, but the situation where he gets it wrong at a later time.

R: Time out procedurally. The approach that this is introducing is one where eventually one would try a number of different paths through the possible future that test the interesting alternatives, but at the moment, to get fixed, we're taking something like a modal pass (5).

E: Let me describe the general situation, and then we'll change from what I thought was happening to another case. There has been some sort of an attack, which was heavier than the previous one, which led us to believe the ninth tank division was in fact attacking. The division has begun to take the actions, as if that were occurring. At the same time, the G-2 is trying to understand more about what the ninth tank division is doing. He's still

watching the seventh tank army, and he has also got surveillance in other areas; so that, let's say two hours later, all of a sudden, on the north flank, the ninth tank division shows up. The previous attack was a secondary attack started early by the reserves and the divisions in contact, and it was not the ninth tank division; and now the ninth tank division is attacking on the north flank.

Now see, some of the resources are still scattered throughout the division area for collection of intelligence, some have been concentrated. Say the signal intelligence people have been concentrating on DFing signals in this area. You would now shift that. You made a mistake in concentrating on what turned out to be the secondary effort. If you began to get some signs of movement ahead of time, hopefully before they attack, and it's enough movement that you say "now I'd better reassess my estimate", and then you finally, grudgingly, reach the conclusion that you may have made a mistake and that there is some sort of attack now happening, or about to happen, on the north flank. You would adjust those collection resources of your own which can easily be adjusted, all are not adjustable, but those that can be then put on that would be diverted to that.

R: Could you give a little more concreteness about how precisely you might have reassigned your resources?

E: You've got a company of surveillance radars. They are not easily moved around. You usually have one platoon with each brigade, and they'd probably stay where they are. They're too hard to get in and out. You have three helicopters which can collect non-communications signals, i.e. radar signals, [?] signals. You'd probably put those up there.

John: So you're saying you're moving ground based...

Ennis: O.K. we've moved the ground based centers up and then there's two other things I would do. I would again ask for help from corps to concentrate some of its movable resources to look at that problem.

Rex: Does it have its own CEWI?

Ennis: Corps has a CEWI brigade. It'll have one or more ground battalions and one airborne battalion, which has a pretty good collection. So I would ask for corps because the corps headquarters is as interested in the main attack as we are. So he will be following it independently and we would have probably been conversing and he may have even have had a tip off that it was coming and I missed it.

Rex: Like from satellite?

Ennis: From something like that, some other way. I would also have been staying in good contact with the division on my left, the German division, and I would certainly want to talk to them right now, to see what they're holding. To see if they have, through their sources, found out that yes, in fact the ninth tank division is attacking right on the northern boundary of our division and on their boundary. So you need to also talk to other people who have collection resources and who make individual independent estimates, but they tend to be overlapping. The corps is looking at everything I am and

more, the German division follows my activities very carefully, because it's going to affect him, and I follow his.

R: Can we tie this down to time? Where about are we in the unfolding scenario?

E: Mid-afternoon. Mid or late afternoon. In other words at 10:00 or ten-thirty there was some sort of attack in the middle. We thought it was the ninth tank division. The division commander has not used his reserve, but he's reviewing his counter-attack plan, blocking plan. I have begun, as the G-2, to move resources to better understand what's in there. Three -thirty in the afternoon, I'm clearly getting some other indications up north which I didn't pay as much attention to in the beginning as maybe I should have.

R: From outside the division?

E: They're coming up on the northern flank of the division, and now there's a sudden heavy attack there and, by George, they say they captured a prisoner from the ninth tank division.

K: Can we back up a minute? Was there anything you would have done at ten AM had you [envisioned?] this possibility?

E: If I thought the northern flank was more serious, I might have even made a trip up to the panzer division, to talk directly with their G-2, because it's right on our boundary. Or I would send somebody I had great confidence in to talk eyeball to eyeball with them. There is a difficulty of getting written reports over the teletypewriter. Voice direct contact is very good. So I might have had closer contact, more frequent exchange of information with the panzer division, because of the sensitivity of the planning. I might have, knowing that you can wear out your flying resources, you can fly just a certain number of hours per day in theory, I might not have put up some of the helicopters up that early (6).

R: With human fatigue?

E: Both aircraft and pilot, yeah.

Marvin: Is there not a secure phone that you can talk to G-2 on in that situation?

E: Yeah, if I thought it was serious, I'd go to the trouble of flying someone up there, I would certainly, by secure phone, do it. The G-2 might not speak English, I may not speak German, I'd probably find somebody I had confidence in who spoke good German go up to their map [?], talk to them, get a sensing of the feel; get both an impression and factual information. If I had realized earlier that that was the critical area, or if I had estimated that that was the critical area (7).

6. PROCEDURAL INSIGHTS

Claire Cardie(SST): All the readjustments and resourcing that you do, is that something that you learn in training?

E: No, you learn what their capabilities are in school, you learn what their limitations are in school, and through your experience, you then are trying to apply them in a reasonable fashion. Much of it is cut and dry. There are sort of rules of thumb, but clearly those intelligence collection resources which have the greatest mobility which can be moved around and all, those would be the ones you tend to play with. Those which do not have a great mobility or can't see deep, they would tend to be with the first brigade, second brigade, third brigade and just stay with them.

R: In what we've covered so far have, there been any spots, any places where a G-2 might make a mistake and therefore where it's useful to know what an expert would do? Or are most of the decisions you are making ones that you'd have no concern that the local G-2 would make right, and therefore wouldn't need your input (1)?

E: I thing experience tells us is that G-2s, because they're working on limited information, are not able to give perfect estimates, ever. And then they go downhill from there to where you can make very much incorrect estimates. The Battle of the Bulge was an example of where they refused to interpret what they saw in the way in which the Germans actually employed their forces.

R: Would we then have to have defined you scenario in more detail in order to be able to say "aha, this what an experienced guy could do that's different from what a less experienced guy would"? Would you have to know more precisely what information he got, and what inferences he made from it rather than this somewhat broader description that we're handling now (2)?

E: You could give me a detailed scenario and I could make bad estimates or the wrong estimates, or incorrect or slightly off the center. The shortcoming of that vs. doing it in reality is the paper vs. the noise and all the other information that comes in. In other words, when you put it on paper you narrow it to the essentials. In addition to that there's just a lot of other things going on which could cause you background, which would also have an influence and you can't represent that in a paper exercise.

R: I understand.

E: It's less than totally satisfactory, understand.

R: Let me rephrase it a little bit. This is a procedural time out. For this exercise to be useful, it seems to me that there have to be at least some places where the observer of your scenario gets some insight, says, "Aha! that's interesting. I wouldn't have thought to do that. And I'm wondering whether the level of our questions and you answers have the right granularity; whether, in order to get these kinds of insights, you'd have to go much more micro than perhaps it's feasible for us to.

Alternatively, do you think at this level, we or a new G-2 could be learning interesting lessons, or perhaps will be, as we go a little further into the scenario? The negative would be somebody reading it and saying, "so what?". That would suggest, either that this isn't a good approach, or that we need a finer grain, or that we need to ask much more pointed questions along the way, than the rather general ones that we are.

CC: Is it a problem of us not knowing enough to be able to say "aha, I wouldn't have thought of that"? I mean, we don't know, I don't know, what's coming across here that might be different than what I would have learned in training, or slightly different. I know that I've just been hearing this all and accepting it all. I'm not surprised because I have no anticipations of anything.

J: I can give an indirect assessment of that. Earlier General Whitehead was going over the Fulda Gap scenario, or the Treysa Defense, as Rex has renamed it. I was comparing the kinds of things that he was saying with the kinds of things that the lieutenant colonels were saying. Now obviously I can't read their mind to say well aha that they would have said that, but comparing the two, some of the considerations that General Whitehead had were very different. In fact, he pointed out things that none of the lieutenant colonels had pointed out. And they were not at the micro level, but in terms of general considerations. So again, I don't know if that was in the back of the lieutenants colonel minds or not, but it didn't come out in what they were saying.

E: I better comment on that, though. The lieutenant colonel was the G-3.

R: What was the context?

E: The context was the choices of courses of action. The lieutenant colonel was being the G-3. He took from me what I had given him as the gospel. I, as the new G-2, came in and challenged the gospel. So remember, I was playing a different role. I did play a little bit of the G-3, but generally what a lot of my ideas were raised on were, "I'm not satisfied that I had it right as the G-2." Therefore, I was going "what's my biggest threat there? What's my next biggest threat there?" and so forth. So I took off on the G-2's track as opposed to the guy who's selecting the course of action.

R: I suppose what my question boils down to is: are we uncovering any difficult choices, and are we getting into the right kind of detail that would help us understand why you advocated the choice that you did. I have a concern that we may not be. Or perhaps we're too early on in the script and further downstream as we allow you to play out your dream there'll be more telling incidents. It's the telling incidents and how you handle them that I think we'll find is helpful.

E: I'm worried that we're not. It's sort of like the father and son thing. The son's going to have to judge whether he hears and what the father makes sense. Everything the father says is not right. The world will be different from the father's world, so there are good kernels in there and there are probably bad kernels of knowledge. With experience being overlaid on top of book learning and not all experience is right.

R: For this to be a successful knowledge elicitation technique, reading or hearing the sequence needs to be in some sense a surrogate for being there. This obviously isn't.

E: The methodology here is good; I'm worried about the general conclusions. In other words, once you get above the factual level and get into the

judgmental levels you change. If somebody else interprets a condition differently then his response could be as good as or better than, or worse than [yours].

R: That I think doesn't matter, even though what you would do isn't necessarily gospel. If we understand why a seasoned G-2 made an important decision, that [a trainee] might have made differently, so that the experience counts for something, then I think we'll be happy as far as our purpose is concerned. Unless anything in particular occurs to you there, I'd suggest we proceed a little further.

K: Before we leave this ..., do you think it might help to ask Ennis to say is there anything that you would do now differently then you would have back when you were a greenhorn G-2?

R: Yes, that would be helpful. Let's address that, and then I suggest that we pause for a moment to let you finish your lunch and then the rest of us can ventilate whatever's on our minds. Do you want to respond?

E: I guess in answering the question if I had to do it over again, what I would do differently, I would have learned my trade better. I would have learned the facts better and I would have tried to also anticipate the breadth of the job, such as the new G-2 trying to understand, above the factual level, what the breadth of the job is. And so I would say, you never do that well enough. I must say I probably did it better than average, but still not good enough. So that's a dumb answer, but it's a truthful one. You suddenly find out you didn't work hard enough on some of these things.

K: Is there any specific decision that you might have made differently back then than you would now and why?

R: In this context?

K: Yeah.

E: I would have studied harder in Ft. Huachuka and Ft. Leavenworth.

K: No, but let's say that when you first came on line. Is there something that you might have missed seeing, you might have allocated you resources differently and been sorry about it later, that you wouldn't have missed this time around?

R: What good has your experience done you?

E: Some of the resources would be allocated cut and dry, no problem. It would be to make sure I've used everything, full up, 110%, getting the best, with slightly different allocation and new thoughts on how to do it, but then getting out of the system 110%. In other words, drive the system harder, which is not knowledge (3).

CC: Harder than you're trained to?

E: Harder than they ever expected to do. And I don't know what that means.

CC: You mean harder than you're taught to use them in school?

E: O.K., let's say, the easy one of this is the Flying Hour program, in peacetime there's a Flying Hour program, with so many hours of a pilot and so many hours on an aircraft. Of course that's simply, everybody realizes, the first thing you do is start flying them into the ground. So you do that, but then also you want to do that intelligently so that you don't fly them into the ground and you've got nothing [left?]. So you then come back knowing your job better so you prioritize and don't use the aircraft. I'm picking something easy, don't use the aircraft purposely on less than the key missions, if you know that's a very scarce resource. Don't get it shot down and don't get it... That's all tuning it, I don't know.

R: Let's let Ennis finish his lunch and let's entertain any discussions that might suggest to us what we should do next, including a mid-course correction.

Craig Cook: This seems to me to be almost a classic case study approach, where you present some examples and somebody just kind of talks about this case study. The only thing that's different here is it didn't really happen, so there isn't any result, O.K., which makes it even shallower than a case study approach.

I also sense that the vague hypothetical nature of the whole thing doesn't allow him to get down to specific details of what it is that he make a decision about. What we're hearing is general strategic level kinds of stuff, which having said it once, seems like it should be enough. But I suspect the thing that makes it really expertise has to do with the ability to use it at the time that you need it and to know which part to use and which part not to use, which he can't verbalize, probably, but can only do through some exercise. So I think it's going to be very difficult for us to get down to deeper expertise, through this kind of scenario, story telling without putting him in a real working [situation?] whatever you'd actually do to go through that kind of a scenario (4).

R: Now would a solution to this, or a step toward a solution be simply to elaborate the information so that Ennis has had to master a whole book full of stuff in order to replicate, without being there, as closely as you can, what he would really know on the ground. I suppose we could ask him two questions. One is, if we could do that, if we could actually fill in all the supporting details for him and, as he moved forward through the scenario, if we could again paint in [the details]; if we could do it, would that have answered your question? If the answer is no, then we don't need to worry whether we can do it.

E: May I comment? Remember when at Leavenworth for four days, we're going to get a chance to watch students do the same thing in the greater detail level. The question is, whether that's going to be worthwhile or not. But that will respond in the way that... Only you won't be able to talk to the students.

Craig: Yeah, we can't talk to them. So here we're asking questions and you're providing insights. There we're just observing them and that's yet another technique and they don't...

Kathy: How about when we come back from Leavenworth, we sort of know what a map exercise looks like. Then one of our experimental techniques could be to give a map exercise with interruptions (5).

Theresa: I really disagree with your [CC?] saying this is all being done on a strategic level. There's some quite detailed [material]. Without getting into the actual nitty-gritty of the pieces of equipment that you look at, and sort of play acting, remember we're just using the scoop full of dirt sort of thing here, rather than trying to do an actual excavation. There is certainly a process that's kind of going on here, where Ennis will describe, in general terms, his next piece of scenario; and then go into detail about what he'll do. And sometimes step back and give us a sort of hierarchial explanation or a sort of "from the manual" or from the outside, to help us organize it, the sort of "by the book" sort of thing, step back and give us an explanation like that. You know, you're getting at some different things here, and if this is just an exercise in trying to see what we can get taking this approach I think we're getting something. I don't know if the purpose today is to get really detailed structure.

R: To capture the texture...

K: The issue is whether the spoonful of dirt, shallow that we're using today, can really get at knowledge that is deeper than what the G-2 would learn at school. The kind of stuff that Ennis could give a G-2 that he wouldn't learn in school.

T: You know, I think the problem we had, that I mentioned before, is that it's hard to know for us maybe to appreciate that, not having gone to school. Sometimes I think that maybe there are things insights here the we, because he's the first person we've done, maybe we should have started out with the person that we assume that we are. We should have started out with that person, and tried to get what they know then we can see the difference (6).

Craig: Just as he's pointed out heuristics that say: "never believe all the intelligence summaries that you see," also there are heuristics about knowledge elicitation which say: "don't convince yourself that you have learned everything there is to know about the subject from an early pass over it." So I'm just kind of cautioning that we may not even have begun to uncover the depth of knowledge that's required to be expert.

K: I think that's obvious. I mean if it were this easy, they wouldn't be paying us money to do it.

T: Another thing that might help, though, even to give us a sense of what, if we go ahead and do this for real, what sort of order we want to do, or how many people we should do. I mean, we need to get a sort of pool of these things; we need a sampling of people going through this exercise and maybe with different levels of experience. That's something else we might work on.

Craig Will: Part of what Craig is pointing out, I think, is the tangibility of the information. My impression is that of what he's said so far, very little of that would we actually want to code into a machine (7). Although everything he said was stuff we'd want to know if we were doing that coding process. I think that one of the problems you get into, is you start actually

coding stuff into a machine and building a system and asking him very specific tangible information and showing him a prototype system and all that sort of stuff. I think that my impression (probably this might have led to Craig's comment) is that when you get into the specifics, the expert might be likely to backtrack on some of the general statements that he made before and start saying things that are inconsistent with what he's told us so far. It's a murky issue about whether what he thinks, when he thinks about it in very general terms, his model of how he does things in the general, really matches up with the specifics within a particular case. He's shuffling this information, mixing it with that information, and getting this output, and then all of a sudden everything becomes a special case. "Oh well, it's just this one little case over here that I don't follow that rule". It gets very confusing and very murky, and that's I think part of why he raised these types of issues.

E: Can I comment on where we're going? We're developing an elicitation methodology, or a family of them or a set. We haven't been told what the application is. We've been told to search for that application. To pick up on what you just said, the Army right now is putting a number of work stations for people to put in what I call the educational and training knowledge, so he can then work on it. So my question is, should we be concentrating on how to best put the training information that people take into that workstation? Or are we then at the more judgmental level of handling inconsistencies and that sort of thing. In other words, what I call the procedures of workstations with all the training agents to help you find things; or are we concentrating on this judgmental individual who has people assisting him at the structure level but he's trying to make sense out of the whole.

R: As far as today's exercise is concerned, we're not addressing the case where the purpose of the knowledge elicitation is to program as far as expert system; though we certainly will be as far as that's concerned. The purpose we're addressing today is a training purpose. And not just any old training purpose, but the purpose of training somebody who's got the standard information, that you get out of doctrine and training and seeing whether we can tack on the additional, the bonus, expertise that somebody with experience can have.

In the particular step-through exercise that we're playing with, I agree with Craig, I don't think it's quite working. The object, that maybe can be achieved some other way, is to try and observe your production rules, if you have any. Part, I think, of what we're missing here, which may suggest a different tack, is that there's not enough circumstantial detail with guaranteed realism being made available, first of all to you (Ennis), and secondly to the reader of the script, who presumably is the one who will learn from it. We're assuming that a set of scripts like this can be useful; either because the reader, or maybe somebody playing/repeating the role, will inductively learn similar production rules directly, or possible will generate a more interpretive structure of his own.

In either case it seems the elicitation needs to have a feature that we're not getting here. This is the richness of the real information and the real circumstances, which will discriminate between an experienced G-2's handling and a novice, which is what we really care about. I have a feeling that, at the level we're handling it, the reader would have no way of saying that this

was a novice or an expert, and that therefore it's not capturing what's distinctive about the expert's knowledge.

K: I think what we need to do is to have two Ennis's, one of them to really play the game. One of them is going to say "Send out the Mohawks" and the other one is going to come back and say "the Mohawks have reported evidence of movement".

T: We're looking at Ennis the expert though. I'm wondering if we should have Ennis play two Ennis's; Ennis before [and after] the expertise. You know when you were asking him what he would have done differently, I'd be interested to see you go through it, almost as you, if it's possible to ...

Craig Cook: Is there such a data base? Does there exist a scenario carried out in its fullest extent with the troops moved from here to there it took them 3.2 hours and they engaged this set here and ... (8)

R: And this is what they saw on their radar screens...

Craig Cook: Now is it possible, if we got a hold of that whole thing and presented it to you in some form, a massive printout, a computer simulation, or whatever, that you could then issue command decisions, "I want to send radar collection over at this", and that the data would be there? If you did that, this is the data that you would get back. O.K., but you don't see the whole thing, you just see the results of what it is that you asked.

R: Even if it's a human playing God on what comes back.

Craig Cook: Well, except a human has to be consistent, O.K. You don't want to get into games playing and making up creative things which will throw off his practicality.

Kathy: More to the point, we probably want to have somebody at the level of just out of school issue the decisions and we want Ennis kibitzing over his shoulder.

E: Remember, the idea was to start out, figure out what you're going to do, go to the school system, which is what I think will be central to this, and then finally go out and look at what's done in the division, which will turn out to be a disappointment.

Craig Cook: There's a key point in your statement which is; is the focus of the project to distinguish elicitation for expertise from elicitation for novices, which deals with what is the nature of expertise and how does it differ from the novice's knowledge.

Kathy: Is it right for us to be focusing on the issue of what makes an expert an expert? If it is maybe what we should use our school solutions for is to give the experts something to kibitz over.

R: My working assumption for just today's exercise which may make it quite unrepresentitive of the total project, is a working hypothesis that an experienced G-2 knows something that we would like to be able to elicit and put in a holding bin, so that later it can be transferred to a novice (if that

transfer can be achieved). This project only addresses the elicitation part of it and not the transmittal part. But if the total process can be achieved, it will achieve something that the Army wants to achieve and it's a legitimate function for this project.

Marvin: I'm not sure I'm following... You seem to have a goal though of being able to elicit just those parts of his expertise that are different from the novice's. But his expertise may be so integrated, and the whole thing may be structured differently, that you can't just elicit parts that are different...

R: I understand.

Craig Cook: I think it may also be that the parts, the real sophisticated parts are situation dependent and can only be elicited under a given situation.

Marvin: I think there's a really interesting empirical question, which I wouldn't ask Ennis and expect him to know the answer, which is whether you really use these general heuristics, in other words, use all the resources, 110%, question the estimate that's handed to you. In other words, do you have a fairly high level knowledge, which then very powerfully generates specific actions? Or do you have a lot of low level rules, in other words, use this type aircraft, use the artillery airborne reserves, use the helicopters? There's a real difference in terms of how your expertise is really represented. If you have the more general approach, it may be more robust. If you are given new collection resources in a situation, you might adapt more easily. On the other hand, it might take you longer to figure out what to do, than if you had these low level rules. It may be that you have both. But I don't think it's obvious that his expertise will be at the level of low level rules, there may be some level, we're just getting to right now that is legitimate. I wouldn't dismiss that (9).

R: Just a clarification of what position I was representing. You've forced me to think about it. I'm not suggesting that expertise is an add-on, but that the totality of what the expert knows represents some improvement, that you'd like to achieve, over what the novice knows. Even if there's very little overlap, there are theories which suggest that novices think in structurally quite different ways from experts, even the experts the novices become. But I'm assuming that we want what the expert knows in totality, and the benefits from that are somehow to be made available ultimately to those that don't have the expertise. The best medium for achieving it may be to put it all in a book, in a training program, a computer ...

Marvin: I wouldn't be as pessimistic about this, I thought it was going rather well. We're not giving him the details, and in fact he's having to generate them himself and perhaps not doing a great job generating details. But what we're getting as a result are some kind of general guidelines. Like, "I would shift the resource if I had been wrong about where they were attacking". Now later when we provide details, we can check for consistency and see if there are two levels of representation. If they're different, which one then, on reflection, you'd say, "yeah this one is better, or maybe they're both working in some way, but we're getting something here".

R: Oh, yes.

CC: I would also think that Ennis' ability to pop in from one level to another is something that an expert, the integration of their lower level strategies to a higher level picture, I think is something I associate with a more experienced person being capable of doing. I would almost guess that we won't find that ability to step back from what they're doing and tell you about it in a less experienced person.

Kathy: The other interesting issue, and we talked about it in other meetings and it really hasn't come up here is what is an expert on World War 3. Are there any?

R: There are only novices.

CC: Then we wonder if you, because of your past experience have a greater appreciation ...

R: An advanced novice.

E: Or a worse appreciation, because I'm captured by my experience.

CC: You have a certain expectation for the way your knowledge will degrade, or things will degrade.

E: That's right.

Craig Cook: So you don't know.

CC: I have a couple of questions about, I guess, I'm surprised at the fluency that you're able to talk about this stuff.

Ennis: I haven't been caught out yet. I lie a lot.

Craig Will(?): And I had two questions about this. You never once said "gee whiz I haven't done this specific thing for 10 years, how would I know that." Now I guess I'm curious, and the other thing is that, well, it's a question about doing vs. training. How long has it been since you've done this sort of task and how, when you were presumably pretty high up in the Army, how removed does one get from this sort of thing? Do you get involved with this sort of stuff enough so that your skill and knowledge keeps getting updated?

E: I haven't fiddled around the G-2 part. Certainly the operations and what things mean on maps and time and space factors and all that. I've done enough time over the years to feel fairly comfortable. When you get me down to the details, depending on how much I've done that, I get less and less comfortable and less and less accurate.

CC: You see, that may be one explanation for why we didn't talk about details, if we brought some person in who really, who did it yesterday, he would probably want to tell us all sorts of stuff about details, and maybe we wouldn't get the sort of high level stuff that we got from you (10).

E: Remember again that you've asked me to be everybody on the G-2 staff. I kept trying to be the G-2, I've got an assistant who is a head of collection

management who I say "give priority to that". I may even be smart enough to say "let's get some helicopters up there". He will in fact have a plan. In fact he will have another guy working for him, who's on duty, who will adjust the current plan and he'll come back and say "we can't do that cause we're doing this or that". So you're asking me to be everybody in a group, by the way.

R: In fact we only need you to say what you would do as the G-2.

E: I can go down and be the detail guy.

R: I think we do not want you to be other than the G-2. In fact how you're underlings implement your orders is part of the malignant outside world (11).

E: You see I came up through that. I was an underling, I was the collection manager in the G-2 staff or the corps staff somewhere in the path. So I've done some of those other jobs.

CC: The other question I had is a question of training. There's a difference between the people who are experts and just do their tasks and people who are teachers. And lots of experts maybe will forget lots of high level rules that they learned because they just do their task; and they only have to reconstitute them in order to train other people. Now in your experience in the Army, is Army a situation where there are experts that do their thing and there are other people who are trainers, or is it typically the case that anyone who's a expert also spends a lot of his time training other people.

E: In theory, some of the people down at Huachuca and whom we should run into at Leavenworth have been the experts, have been division or corps G-3s or assistants to G-2s, and they are now back teaching.

CC: I have a suspicion that when you have an expert who's also a teacher you may get two layers of knowledge, two layers of representation. There's the way the guy really does it, and then there's the way that the guy tells other people he does it, and the second layer may be to some extent phony (12).

E: When the instructor starts telling the war story, that's right, and gets away from the text.

CC: Well, or it's hard to articulate something or you need to oversimplify it so somebody can understand it. So you make up things that aren't really literally true about how you do stuff, and you figure that when the student gets to the highest level of expertise, he'll find his own way of solving that problem.

7. KNOWLEDGE STRUCTURE

R: I think I'm going to want to move us along before we've exhausted these issues, just so that we've covered a couple of bases. Does anybody here want to try out any ideas from your particular perspective, Craig or Marvin or John, that would enable us to use this as a test for either knowledge structures or elicitation techniques. If there's not, then there's something else I want to go on to, but if there is anybody who would like to test anything out I would like to give priority to it.

John: Yeah I would. If anybody else wants to I'll divide my time up. Anybody else? O.K.

Marvin: Are we meeting again, Rex?

R: That's one of the things to be discussed. I think you and John need to decide whether you think it would be useful or not. I've committed a certain amount of resources and I'm game to follow up, but I think it's your judgments on whether [there should be] a next step along these lines. I'd be interested in doing it, but I think that's your choice.

John: The purpose of what I'm going to be asking you now is to try to get a sense of overall structure to what some of the things you've been talking about. You talked about things like: wanting to know where the enemy threat is, and what he can do to me, and where he is and so on and so forth. I'm going to ask you a very general question. Why does all this matter?

E: It goes back to the division or corps mission. I'm on the division commander's staff, he has been given a mission to defend the piece of ground. I'm concentrating on what I thought were the most important threats to doing his mission. That's the only reason it's important, mission accomplishment.

John: So mission accomplishment is your overall goal then is what you're saying. (1)

Ennis: Yes.

J: Then, you're looking at threats to this mission accomplishment.

E: There's a second one and that is the ability to carry out the next mission. In other words, I do not want to exhaust all my resources so there is no capability tomorrow.

J: O.K., so give me a summary statement then. When you're thinking in terms of mission accomplishment and next mission. What is it that you're trying to do then? I mean, give me a sentence that describes all your concerns.

E: I am trying to describe for the division commander what the greatest enemy, terrain, weather impacts there can be on his accomplishment of his mission.

J: On the enemy's mission.

E: On the accomplishment of HIS mission. In the defense, 1) what of the capabilities that the enemy has would do him the most damage and 2), the harder part, what they're likely to do. Which can have a significant impact on things.

J: O.K., lets start now. You didn't cover the issue of next mission, so, don't go into the detail yet, give me a general summery. In other words, I have a mission, what am I looking to do? In general, what are you looking to do?

E: I'm going to tell him what the enemy is going to do both in the near term and the longer term, which hopefully might be out at 48 hours or longer in a Euoropean-type fast moving warfare. Or at least out to 24 hours. It could be out to two months in a Vietnam situation, or 6 months.

J: So you're looking to see what the near term and long term threats are.

E: Right.

J: How do you determine what they are?

E: In the near term, I look at the forces, and the terrain and weather, which can have the greatest impact on our ability to accomplish the mission, which in these cases has to be large, aggressive, mobile heavy firepower forces. Now if we [he?] had the world's largest airforce, I would have included that in the possible threats, but that wouldn't throw us off this ground. Those two major forces there could throw him off that ground.

J: So how do you determine, O.K., so you've given some criteria; large, aggressive, mobile, and heavy firepower, what criteria are you using to evaluate, to determine that's a threat. So they all impact into some notion of force ratio.

E: And his mobility characteristics, and hidden in the force ratio are the capabilities of his weapons systems, and leaders and all that.

J: O.K., wait a second. One more time, go through all that.

E: Well, in force ratios, his mobility capability, and hidden inside his force ratios you'd like to have some idea of the relativity of weapons capability. In other words, the normal way of measuring force ratio is he has three battalions and I have one, that's three to one, but he might have a weapons system that makes him equal only one to one, or make him seven to one, so there are some qualitative adjustments.

J: So mobility and weapons capability. What else impacts on force ratio?

E: As I said, the terrain and weather are always there. His previous practices, is he aggressive? I mean, fighting the Russians is different than fighting the Chilians.

Craig Cook: Fighting on home ground may be different from fighting elsewhere.

E: That's right, it all depends on where you are also.

K: So you're saying that all those things are part of force ratio; mobility, capability, previous practices, and ...

E: Force ratio is a rule of thumb which is generally, I've got so many battalions and you've got so many battalions. But then they have to be qualified by the other factors.

K: So you compute the *normal force ratio* and then you say "but he's mobile" and so you make an adjustment, and then you say "but the terrain is such and so" and you make another adjustment.

E: But see, the commander has also studied the terrain, he also knows the forces, so he has already got part of that knowledge himself. He knows its a totally mounted division. Everybody's on tracks and wheels, so he's already taken that in.

K: Are you going to give the commander standard force ratio, or are you going to say "this is a force ratio that I have adjusted to take account of weather and terrain and mobility and all these things."

E: The G-3 comes up with a force ratio and then I give him the red forces and then he takes his blue forces and says "aha." And we together say it's seven to one in this area, two to one in this one. It's a joint project, but the G-3 is the leader in that, providing the blue force data.

J: How do you determine what long term threats will be?

E: Size and distance and time to use or deployment. In other words, distance from the front in this case. And anything else you know about their capability to initiate an attack. For example, suppose they've been in the combat for two weeks and been withdrawn, they may not be ready to attack tomorrow, but a week from now they may be in a much better ...

J: How do you determine if an enemy is sufficient size to pose a threat to you? How do you relate the magnitude of threat to the size of the enemy force?

E: From the G-2's point of view, I know that he [enemy?] has a doctrine of how much of a force ratio advantage he would like to have before he attacks in artillery, in tanks, in manpower, in divisions, in aircraft. I know that's been the historical way of doing it. What I'm not sure is would it be in this situation. I'm starting off on the premise that it is. I also know that we think we can defend the three to one ratio successfully and so therefore we know he likes to have say six to one in the breakthrough areas, so based on my education on his doctrine, I would come up with that. Can I make a comment and interrupt?

J: Sure.

E: I encourage us to keep our eyes out to see whether or not, like in all the computer workstations that are now being introduced to the Army, could we help them in how to build the knowledge that should be in there, which is sort of the semi-factual knowledge and the accepted rules of thumb, six to one, you know, ratios. The way they've done it is to take what has been done manually and try to put it on a computer. I would just suggest we keep our eyes open to see whether through elicitation methodology we could help them come up with a better way of putting this on. That's kind of a wild hope. I'm not trying to press that idea too far, but I would say we ought to keep our eyes open, because there's a little bit of reluctance to accept the workstation solution as being a good way to train that young captain in the future.

R: I'd suspect that this will be the subject of another session. Inside the total expertise, there are specific places where there's some promise for computerized expert systems, but I think that's not today. I don't want to interrupt John's flow, unless in the course of this particular scenario, it happens to dawn on you that, hey, here's a place where it would be promising to have expertise computerized, but I think we should let John run his course.

J: How do you determine what distance the enemy has to be at before it's a threat?

E: Again, that's an examination of a road map and terrain and a straight computation of how long it would take them to make the move, added on top of his normal doctrine. In other words, if you accept, for example that maybe the second echelon armies will sit off at 200 km, when they start to move forward and you see they're inside of 100 km, and maybe at 50 km, then you begin to think that's an important threat. The road map then does not permit an easy diversion left or right off a great distance, and they might not be attacking you, but it would appear that they would come in and attack the division on your flank. So it's distance and location, and the terrain that supports it.

J: In other words whether they can get at you.

E: Yeah. Very simple.

J: O.K.. time issue?

E: There's the standard rates of march, standard condition of roads, you can compute the time that it will take them to make the move.

J: Now, how do you determine how much time is a threat for you, that the enemy could get there. How much time are you going to worry about?

E: It's taught in the book. The division commander thinks out 24 to 48 hours, I think the corps commander thinks out 72 to 96 hours.

J: So that's what you're saying ...

E: He tries to plan ahead that far. At the G-2 I should be trying to get out the 48 if at all possible. I've got to worry about right now, but I should be doing part of my thinking thinking out further ahead.

J: O.K., so that's doctrine based, what you're saying. O.K., and capability to initiate, how do you decide what their capability is to initiate?

E: I'm sorry, the capabilities to initiate ...?

J: The attack.

E: Again, I think the quick rule of thumb is the force ratios.

J: So, where they are out there?

E: Well, you first of all have some indication of what they've been doing. If they've been attacking, and they've got more forces moving up, logically you would expect them to continue the attack.

J: Well, these are long term guys, so they're not attacking.

E: Well, maybe they've been attacking you, but you've been able to hold them. Now there's a reinforcing force coming up, a reserve, second echelon, who will continue the attack, and he changes the force ratio equation from 2 to 1 in front of you to 7 to 1 in part of your front.

J: So, it's the reserve plus the guys on line.

E: Yeah.

J: Let's look at this example here, which is one you're familiar with. All right, so, I'd like you to make some sort of assessment now of what the threats are to the 52 mech division.

E: For background I'm assuming the head of the column ... what time is that?

J: 6:00 A.M.

E: So at 6:00 A.M. the head of the column is 55, in other words I have instantaneous information, or was that midnight last night?

J: No, that's right now.

E: Do I know that right now? I'm asking, there is a time delay, and I want to make sure I recognize that. A pilot airborne saw them moving forward with their lights on, saw a column 100 km long and reported it.

J: For now it's...

E: Flights report in through the air liaison officer to your CP and he walked in and said, "one minute ago," (the reason I say this is there's normally a time limit), "one minute ago our four pilots saw a column of vehicles with their lights on appeared to be more than 100 km long".

J: Assume the information is 100% accurate. God just told it to you.

E: O.K.
(laughter)

K: It's good that we have God on our side.

J: No, he's just flying an aircraft up there.

R: What are the markings on the aircraft?

J: Halos and wings.

E: O.K., first I would calculate the worst case, assuming that they have refueled and had their orders and knew what they were doing and required no further topping off of supplies in any way, particularly fuel...

J: Wait, hold on a second...

E: I would probably just calculate the time looking at the road net, I would calculate the first place at which they could attack in strength assuming they continue their march.

J: O.K., so time, now you have an armored division as your lead element. What's it going to do? How quick can it get to you?

E: 50 km? Soon, soon. With the round about, it makes it 80 km, at say 20 km per hour, average speed, they might be here in four hours. They might be at the point of contact in four hours. That's worst case. They would probably have to break into some sort of combat formations. If they were going to coil up and top off their tanks before hand, 8 to 12 hours, or they could take advantage, this is 6:00 in the morning, they might take advantage and attack tomorrow morning, let's see, this is August, daylight's about 3:30? 4:00? Ah, a little later, first light tomorrow morning. Make a passage of lines during the dark. So you know, they could attack by late afternoon if they just moved and attacked, or they would have time to come up and make a passage of lines in the nighttime and attack at first light.

J: Why do you think they might wait all night?

E: To give them more time for reconnaissance, though it would give them time... The reason I think they would attack at daylight rather than during the night is that your bringing people that have never seen the battlefield forward, making a passage of lines after dark, conducting a night attack on strange terrain, and having to go from column into attack formations, and that's difficult. If you gave them more time to move their forces up, to do the last minute reconnaissance, to have a good artillery preparation, and jump off at first light, they could have air support during daylight. They could have better observed artillery support during daylight and their direct fire weapons would be more effective. So, they would get their firepower together better in daylight, they would get the advantage of surprise if they did it at night.

R: Excuse me, I need to interrupt. I'll have to leave in a few minutes. I just wanted to make sure a couple of things were covered, but I see no reason why you shouldn't continue after I leave, it sounds like you have a productive dialogue here. But while everybody is here, let me repeat what I said before, that I very much appreciate any comments on what you think you learned from this experience, at any level you think might be relevant to the project. I'd suggest probably a memo to John, with a copy to me, and whoever else you think is necessary. Is there anything that anybody wants to raise now? I see no particular advantage in raising it now, except that if there is something that anybody wants to raise or question that's best done when we're all here, I'd like there to be an opportunity to pick it up. O.K, if not. then I will excuse myself. I think your pursuing this as you see fit makes good sense. Do you think it's important for the rest of the group? Well I suppose the rest of the group can decide if they want to stay.

E: I'm wondering if this sort of one on one [isn't the best way to proceed].

R: That's right, but the assembled gathering can decide if they find it helpful to eavesdrop on this. I need to excuse myself. Thank you very much, Ennis.

J: Due to practical constraints, I don't want to consider this too much longer.

Craig Cook: I'd agree with that.

E: I was hoping we would end by 2:30.

J: Oh, even before that.

E: Good.

J: O.K., when last we left our heroes..., you were saying that there's better preparation if they attack the next morning, but more surprise at night (2).

E: For example, if the front line attacks were being successful and they were actually moving our forces back, they might tell them to continue the attack in the nighttime because they really aren't meeting resistance.

J: Is that because, then, the added advantage of the better air support and artillery support and more familiarity with the terrain would not be necessary?

E: Yes. The advantage of the maneuver would outweigh the advantages of firepower. Speed would be the [critical factor?].

Theresa: Is that just general work related knowledge, or is there something in Soviet doctrine also would ...

E: Soviet doctrine, U.S. doctrine, taught in the schools... I mean there's nothing here that the guy [doesn't know?]. One other comment. When the guy comes out of Fort Leavenworth or out of Fort Huachuca, in many ways he is the best trained for the job at that point. Then he goes off and does something else for 6 years, and then they make him a division G-2 and he's trying to remember what he learned back in school. He knows other things he didn't know in school, so the guy coming out of school is not a novice. He's had good basic training. He will know this sort of thing. He will do it faster than I will. And better (3).

J: You seem to be invoking a new concept here when you talk about maneuver and air support, artillery support, and all that, which are factors which contribute to the success of an attack. O.K., would you, as you know them, say what they are, what factors do contribute, other than, say, size of force and sophistication of weapons and things like that. Some of these more, I don't know if you want to call them intangibles, they're not intangible.

E: O.K., we've now moved from the G-2 by himself to the general knowledge. This is as important to the G-3 and the commander as it is the G-2, but ...

J: The G-2 knows about this ...

E: Yeah. Everybody should have a common basis of doctrine to start from. Let me give you an example, if I can move a division column 40 km a night without moving a shot down a road, taking a chance that the head of the column will get stopped somewhere and there will be a fiasco. But if I don't get piled up and disorganized in darkness, which is very complex, if I can somehow break through any thin resistance and then go 60 km, then maneuver means everything, because if I am 60 km in his rear, then I have turned and made useless all his defensive positions. If I don't think I can make that breakthrough of the crust, then I want to get all my firepower lined up and get all my troops organized to get the maximum effect to breakthrough and then exploit.

J: Now you've involved a new concept, which is factors, or criteria, for determining success of a mission, an attacking mission, which namely, breaking through into the defenses rear.

E: Well, my mission, as I say, is the same, I guess I was looking at two options.

J: Well, you're talking about the enemy's mission now.

E: That's right. The enemy's mission was to seize crossings over the Rhine. This was the army, the second echelon forces mission, to seize crossings over the Rhine, 100 km in the rear. I am the lead division. Soviets don't give you this flexibility, but let's say that I have the option of making a hasty night attack, breaking through and then going like the devil. Or I can put my forces in a ford assemble area, send my leaders forward, do the final reconnaissance, get things lined up, get my artillery in position, pile a lot of artillery and firepower into it, and then try to break through at first light and then reach the goal. You're now down in the judgment of courses of action, you see those are just ... I've kind of led us astray.

J: I think we'd better take a time out and summarize this. You're surprising me now, and I don't know if it's because we've been talking about the scenario. I've got you in a generative mode instead of an interpretative mode. Because I would expect, just by asking you what factors make attacks strong, or what factors do attacks, you'd just read off a list that says 'Field Manual X'.

E: That's right, the principles of war.

J: But now when I'm asking you this question, you're describing in concrete terms an example of what would have been a successful attack. I'm trying to wonder if that's how you think about it or or if by getting you in the scenario I've got you in a generative mode, so I've just happened to put you in a piece of knowledge that now you're working in.

Marvin: You're coming down this hierarchy, and I think you're right, I mean, you had him down at this level, you asked him a question that might have sent him up there, but it didn't, that's exactly what I was saying.

J: Right, So I'm just trying to see if you have any reflections, if I've got you in scenario mode now because through having talked about this scenario a lot during the questions. Or if that's the way you normally think about, I mean do you think about the objectives ...?

E: I guess I am, what's the objective, objective oriented, and I guess that's sort of leading my thinking.

J: I mean ...

E: But I'm not sure, I mean, everybody thinks differently, so ...

J: I understand, but I'm talking about you, just you, I don't care about anyone else.

Craig Cook: You've also made a few comments along the way about "it's in the book", this is textbook kind of stuff, is it possible that you're bored with this topdown approach, that ...

E: No, no, no. I was just trying to indicate that, I guess I was trying to lend substance that what I'm saying is not terribly imaginative, that all G-2s, G-3s and commanders ought to come up with generally the same response. Now there's some who would consider a set of totally different factors, time and space were kind of the drivers for me on the first part. But you are taught a lot of things, you are taught the rate at which forces move, you are taught to study the terrain and road map, you are taught to, you know, and then use it.

J: I'm kind of thinking that, I mean I could keep doing this, but I'm kind of satisfied that I've a feel for what's happening, so we could adjourn.

ATTACHMENT A-2: COMMENTS ON MICROCOSM TRANSCRIPT

These comments are keyed to numbers in the text of the transcript in Attachment A-1 (consecutive within each numbered section).

1.0 INTRODUCTION

1.1 The ground-rules for the session, distributed in advance, are in Attachment A-3.

1.2 The Treysa Defense Scenario is an example of a Fulda gap scenario in Western Germany. The U.S. is defending against a superior Soviet force threatening a communications center at Treysa. The subject, General Whitehead, had studied intelligence summary and other material, which had been prepared (for another purpose) for a division level G-3 preparing to make a recommendation between three courses of action within a 4-hour period.

2.0 BROAD GUIDANCE

2.1 This refers to two pages of notes EW had prepared ahead of time (see Attachment A-4).

2.2 Knowledge item: a key G-2 function is not to be a knowledgeable expert but to use people who may be.

2.3 EW is going *straight to narrow scenario-specific* guidance, though asked to be broad initially. This may suggest that his most readily accessible knowledge is *generative*, and more than that, *instantiative*, i.e., expressed as illustrative instances. This is different from a production rule, where the defining conditions are stated explicitly. In a sense, EW's knowledge here is not quite instantiative. The conditions being specified in the pre-session documentation would only be strictly instantiative if EW were actually in the real world situation, where much of the conditioning information would be *implicit*, and experential, without being verbalized. The instantiated knowledge could only come out of the expert responding to the real situation, including all the subtle cues that do not get into writing. The conditioned reflex would be an example, where the subject may not be conscious of any rules generating the response.

It may, of course, be that EW's *total* knowledge is interpretative, but not that part of his knowledge which goes beyond that of the trainee G-2, e.g., it does not include the largely interpretative material taught in school and given in doctrinal documents.

2.4 Knowledge item inferred from instance: "check intelligence reports for plausibility, as generated by doctrine and prior judgment. If this generates major uncertainty, you need more information." EW did not express his knowledge in this production rule form. I induced it. We could have pressed him to come up with a production rule or confirm one that we inferred. This can be raised in a follow-up elicitation session (which I do not recommend in view of the shifting emphasis of the project). Another implied production role: intelligence reports at the beginning of the war are suspect, because no one is yet an expert.

2.5 The production rule here was expressed fairly directly, rather than needing to be inferred from an instance.

2.6 Knowledge item in form of mid-level rule: "focus on 24 hours ahead and resist any inclination to report the present or past only." This is the kind of guidance that might go into a doctrinal document and is, perhaps, already there.

2.7 Knowledge Item: "Expect attacks at boundaries, because enemy thinking is likely to be...." This knowledge is already in doctrine, i.e., part of the knowledge we are eliciting is a recapitulation of doctrine. Possibly all of the broad and narrow generalizations from EW which are not specific to this situation derive from doctrine. Perhaps the loose structure of this part of the session means we are only getting at the readily accessible generalizations. Perhaps we could have pulled original, non-doctrinal general knowledge out of EW, if our elicitation had been more active.

2.8 Knowledge Item which is an instantiation of a more general, unstated, rule: "Get and "fuse" many different types of information (analyses)." This suggests that a potential mode of knowledge elicitation is for the elicitor to *construct* a generalization (based on low level rules or instantiations) and play it back to the subject for confirmation (e.g., the above inferred generalization about plural analysis).

2.9 Knowledge Item, which is a recommendation, followed by an explanatory principle: "Find out about the larger forces in the rear, because it has a greater impact on our division." This is a common case in this session.

2.10 A last--and successful--attempt by the elicitor to extract guidance not specific to the scenario. Most of it is stipulation of instantive advice given earlier (e.g., "Speed is more important than accuracy.")

2.11 Reiteration of EW,s early meta-rule: "G-2's task is management."

3.0 SPECIFIC INTELLIGENCE AREA: ASSESSING ENEMY MOVEMENTS

3.1 Pre-session, EW had been given a list of half a dozen potential intelligence items to focus on, including the location of enemy command posts, put forward by DSC staff with army experience. EW proposed, instead, an item which he felt should have higher priority--whether the 9th Division is moving.

<u>Technical aside on knowledge elicitation methodology.</u>

An important kind of knowledge, relevant to the new thrust of the project (intelligence analysis), and quite likely to be where the expert has something to offer over doctrine, is the *interactive* aspects of intelligence, i.e., the alternation of assessment and information gathering on any particular requirement; in this case, the priority intelligence requirement is enemy reserve movement. There is an initial assessment--that it is stationary--which is evaluated as suspect, based on conflict with other evidence. This stimulates plural analysis--going off to quite different sources of intelligence, such as corps mohawk and visiting the German Corps. The analysis needs to be continually updated, so that the commander has the

best current estimate in time to make relevant decisions, e.g., where to move his own reserves.

A computerized analysis aid, focused on fusion, could be sequentially updated for probabilistic assessment of the PIR. In this case, the standardized output might consists of a list of current hypotheses (9th Division stationary, moving south, moving north), with either probability numbers or verbal likelihood statements. Immediate input could be a list of intelligence sources with some measure of their diagnosticity for the target issue, e.g.: intelligence summary, prior judgment based on doctrinal assumption, surveillance aircraft report, German report. A key knowledge elicitation issue is how these input questions should be posed, so as to make best use of expertise. This surely dominates the convenience of the logical algorithm, linking input to output. Bayesian updating would be a natural algorithm, which produces output in the right form. However, it calls for prior judgment (in the same form as the output so that it is probably O.K.), but also likelihood assessments (as a measure of diagnosticity).

In its exact form, this requires assessments of the probability of the intelligence report given possibly hypotheses about the target issue (e.g., PIR). Perhaps we could elicit a measure of "surprise," in linguistic terms, such as "inconceivable," through "likely" to "inevitable." The machine would need to translate from verbal input to quantitative input, to quantitative output, to verbal output. The important knowledge elicitation technique issue is the trade-off between defining input which is easy to elicit; and input from which relevant output can most readily be inferred. For example, a "persuasiveness" scale may be easier to get than a "surprise" scale, to link an intelligence report to a hypothesis, even though the latter fits better into the Bayesian updating algorithm.

Knowledge to be elicited in advance of the battle to be aided can be of two sharply distinct kinds. One is of the expert G-2 to enhance the local G-2, of the type we are eliciting from EW. It would be doctrinal types of information. My intuitive judgment is that it would be too difficult to elicit this information in advance of any particular battle in a way that would be relevant after the battle commences (though I suspect it will be a seductive idea to army bureaucrats!) The way for doctrine, and expertise beyond doctrine, to be made usefully available I feel sure, is by more conventional training and briefing of the G-2 and/or his staff. Not computerized.

However, a generic fusion aid based on analytic knowledge elicitation seems quite promising. However, the substantive knowledge to feed it will always need to be tailored to the local topical situation and I am not optimistic that that part can be computerized.

A more ambitious extension to this fusion aid would permit projecting the value of intelligence collection options. The underlying algorithm might be decomposed error analysis if the target issue is itself quantitative, e.g., how long until enemy attacks? In this extended aid, the diagnosticity of the intelligence needs to be assessed *before* it is received. It would need to be a more readily interpretable version of the mathematical concept of "the prior expectation of the posterior credible interval."

The above discussion all has to do with the *use* rather than the elicitation of the knowledge, but I do not think they can be usefully separated. You must determine *what* knowledge is to be elicited, and in what form, before you can meaningfully address the appropriate way to elicit it.

3.2 Locatio of the Command Post is in an inference hierarchy. It has some interest in its own right (so it can be killed). It is also diagnostic of another IR: the location of the 9th Division. In principle, we could design an expert aid which would assign priority to IR's based on a "value of information" algorithm. I don't believe one can anticipate enough of the specifics of the problem to do much of that in advance.

This supports the idea that intelligence analysis can be more readily computerized than intelligence collection management (since the latter requires more considerations to be taken into account).

If the knowledge that is to be elicited comes from developments in battle and at short notice, what's a significant constraint on the knowledge elicitation technique. Elicitation may itself need to be computerized, since there is not likely to be an elicitation specialist at hand. In addition, the subject may have to be trained so that he can respond to the elicitation.

3.3 The influence diagram program (e.g., as developed by Ross Schachter of Stanford) might be a promising vehicle for the kind of inference linkage in the knowledge elicited here. Unless there are certain very standardized kinds of inference which occur often enough and in a consistent enough form there may not be much scope for pre-programming, beyond supplying a generic tool which must be adapted to the specific circumstances *in the field*. This issue of pre-programmed decision aids was the subject of a substantial Navy research effort in the 70's, funded by ONR as the Operational Decision Aids program. (Brown, et al., 1974, 1975).

One of the rare situations to justify pre-programming was assessing range to the target (Bromage, et al., 1983). It is not clear that there is anything of comparable promise in a battle combat situation, where the target ranging problem is less dominating than in submarines and is subject to less standardized sources of intelligence.

3.4 This was an attempt to get at a *deductive* mode of thinking underlying the intelligence prioritization. The conventional value of information paradigm was clearly not near the surface of EW's mind. This does not mean that we could not elicit knowledge in that form; only that he was not inclined to volunteer it in that form. A useful follow-on exercise would be to conduct a structured deductive knowledge elicitation, compare its implications with subject's direct recommendation. We went part of the way, by having EW discuss the impact on the three courses of action, if his intelligence collection comes out different ways. This would have implications for how important the collection activity is, which may not coincide with his direct assessment.

The type of knowledge elicitation we are exploring here does *not* lend itself to computerization, and therefore is probably not worth pursuing on this project.

3.5 Another kind of computerized knowledge is a directed search of agenda items, i.e., what issues to look at in certain circumstances. This would be a kind of interactive exploration of a doctrinal data base.

A computerized training manual would be a candidate end use for knowledge elicitation, but possibly out of the scope for this project.

3.6 In the normal course of apprenticeship, the trainee elicits directly from the expert by watching and presumably asking. No scope for computerization here.

3.7 Most direct form of inductive learning is watching the expert in a real situation. However,EW believes that commentary by the expert is helpful too. A version of the knowledge transmittal cycle, i.e., knowledge elicitation--presentation--use, is directly between expert and trainee in a training situation. Low priority now on this project.

3.8 A significant class of knowledge is how to evaluate an item of intelligence. Trainee's knowledge base includes generic data on accuracy of different types of collector e.g., "most cannot see more than five km". Scope for a computerized reference book, as an intelligence analysis aid, and intelligence collection aid. Not of great interest to this project.

3.9 Knowledge item: example of low confidence intelligence, implying needs to dig deeper with more extensive collection.

3.10 Knowledge item: how to assign confidence to source of intelligence. Generic rules of thumb on quality of intelligence reports.

3.11 Instantiative reasoning that leads to conclusion that the 9th division is in a certain place. Different indicators at different levels in an inference hierarchy converge, e.g., a mix of forces characteristic of a certain kind of division. What constitutes conclusive evidence neatly fits into paradigm of hierarchical inference.

3.12 One way to elicit knowledge, of substantial practical importance, but probably not what we are now after, is *interactive* elicitation. The *user* of the knowledge interrogates database (human or computerized). Essentially, each question is prompted by the answers to previous questions. Just what is going on here: we dig into what is behind EW's conclusions, with selective probings. DSC has been developing computerized prototypes of this (Ulvila and Thompson, 1985; Brown, 1986). A computerized v[illegible] requires that *all potential* information to be called up must be pre-programmed. This may make sense in some kinds of repetitive or large-scale single decisions, which can justify the set-up cost, but probably *not* division-level battlefield decisions.

3.13 Type of knowledge: inference about nuclear weapons. A good example where established doctrine is lacking because it is new and sensitive, and where eliciting expert's knowledge, is therefore, of great importance. For much the same reasons, expertise is going to be very scarce--and will be of the deductive, not inductive, kind (i.e., there will be almost no experential knowledge or even reasonable surrogates for it). Could be in an interpretive form, including the *imposed* interpretative form of a structure such as PDA.

This is an example where type of knowledge is associated with knowledge structure and derivatively method of elicitation. One might expect change during the course of a war, from deductive to inductive as doctrine is replaced by experience.

3.14 Type of knowledge: principle of war.

3.15 Here we have extracted a complete PDA-like chain of reasoning, i.e., he explicates why enemy movement information is important to get intelligence on; in terms of its impact on commander's actions, i.e., the intelligence is important because it tells him what to do, but he stops short of considering the cost of errors.

Implication for knowledge elicitation on action decisions: advice bearing on collection management decisions can be specified at different levels of generality: send someone to talk to the 23rd Panzer Division; assess their intelligence on the reserve movements; get German information on enemy movements; get information on enemy movements; find out about the most serious threat; get information where the cost of error is greatest; implement this VOI paradigm of PDA. Each step could be inferred by implementing next one along.

Issues relevant to knowledge elicitation are: How much of a total reasoning chain is the subject applying? *Can he supply deep levels of it*? Should the knowledge elicitation force him to? What if the subject is incoherent (i.e., deriving the advice at different levels and deducing implications)? One major mode of knowledge elicitation to *enhance* the *expert's* knowledge, by giving it logical support (e.g., take it into PDA and/or plural analysis framework)? Alternatively, knowledge can be *selectively* distilled from the expert, which, on some grounds or another, is judged to be most valuable, i.e., you may not adopt his advice which is based on he is *not* an expert in. He says: "Send S-2 to Jones to talk to the Germans." His expertise tells him that complementary knowledge about enemy movements is of high value, which is also based here on the "knowledge" that the Germans will have valuable information which they are prepared to share. Somebody *else* may be the expert to ask on that aspect. Selective elicitation of knowledge is helped by having an inference structure (e.g., PDA) provided by the knowledge engineer, not by any experts.

3.16 Illustrates the importance of considering the whole "knowledge transfer" cycle when designing any part of it, such as knowledge elicitation. This raises the question of having the knowledge *represented* at the elicitation session itself, e.g., a video tape of it, possibly with commentary added afterwards. The knowledge elicitation for that will be quite different from one where the knowledge is to be transmitted through a computer program.* A knowledge elicitation needs to be considered in context.

4.0 OPEN DISCUSSION

4.1 *Selection* of knowledge to elicit is an important part of knowledge elicitation. It requires *substance* expert as well as a knowledge engineering expert to design the strategy.

4.2 Specifying indicators (e.g., limiting features of the terrain) helps assess target facts to meet intelligence requirements (e.g., direction of enemy movement).

4.3 More prompting of the value of information paradigm.

4.4 Dynamic updating of information. Major type of knowledge missing in the training database appears to be the evaluation of multiple collectors whose output will be fused. We learn individual collector capabilities but not how to put it all together. (True?)

4.5 Part of analysis is adapting intelligence to the specific requirements of *this* commander.

4.6 Generic knowledge: Don't get distracted by detail, except to check on its quality by spot check.

4.7 The importance of knowledge to be elicited from experts that goes *beyond* regular training. EW believes there is substantial value. It has bearing on what kind of knowledge-based aid would be developed. It bears on how much of the aid replicates the training base, as against what's missing from it, or the union of the two. The implication might be to *augment* training with additional material, acknowledging that it might need to be in a rather different form. (e.g., video tape of a session like this one).

4.8 Assessing uncertainty is a major priority of G-2. When looking ahead, how should uncertainty be handled and communicated in an intelligence analysis aid?

4.9 Restating and interpreting the principles of war.

4.10 Critical importance of *fast* estimate, even if poor. Part of the analysis problem is *when* to report.

4.11 On the dividing line between collection and analysis is what to look at or who to ask, which is basically already within reach? (e.g., asking the brigades if they see any signs of reinforcements).

5.0 STRUCTURED ELICITATION: STEP-THROUGH SIMULATION

5.1 The ultimate function of step-through simulation here is not quite clear. Assuming a particular U.S. course of action, we could be addressing the probable consequences of the action, which is part of the intelligence analysis function. A potential analysis aid here would be based on knowledge from an *analysis expert* how to do this kind of step-through simulation. This is not something you would likely do on the division level. Requires too much effort, time, and expertise. Step-through could also be used for training, to provide *illustrative* intel analyses as the sequence unfolds. It is the surrogate for watching a senior perform in real battle.

5.2 Much of the art of intel analysis is the beaming of attention. Attention itself is a scarce resource.

5.3 Force ratios are an example of intelligence requirements whose analysis could perhaps be pre-programmed. However, it is unlikely that the diagnosticity of the indicators can be set much in advance, but that would be something to check with military experts.

5.4 Information seems so complex, rich and situation-specific, that it will appear that the only generalization possible has to do with underlying logical structures for making decisions or inferences (which have a function we are eliciting knowledge for). This argues strongly for imposing a PDA structure.

5.5 Sequences that get selected by step-through should capture not only what is most probable, what is most important. This argues *against* random sampling at each node in the usual way, which may miss the more interesting, if rare, sequences. The analysis will not be distorted, provided each simulation trial has the appropriate probability weighting, when not equal, as in conventional simulation. This is an area for methodology development.

5.6 Some unfolding of data in the step-through sequence casts light on the quality of an earlier collection management decision in the sequence e.g., Misjudging who is attacking and where led to surveillance helicopter forces being wasted, i.e., there is less flying time now available for precious purposes.

5.7 The "feel" of human collectors (as opposed to their facts), is an important item of intelligence to analyze. How do you measure that feel? Letting them talk in their own terms; or by extracting answers in a preset (or perhaps unnatural) format. For example, posterior probabilities, as against prior and likelihood functions. A computerized aid for eliciting this feel would be promising.

6.0 PROCEDURAL INSIGHTS

6.1 Elicitor is clearly having difficulty getting at what the expert thinks is knowledge incremental to the trainee. This is what we are supposed to be eliciting in this case. As a result, we are probably tapping into his total expertise, not his incremental expertise over the trainee. This is probably alright. Important issue of how finely defined a given situation needs to be (e.g., in a step-through sequence) in order to elicit the kind of knowledge we are really after (e.g., the increment between an expert and a trainee).

6.2 One way to capture the detail that the G-2 expert would have is to make sure we have another resource expert who can both supply what he (the resource expert) believes the G-2 expert would know and also anticipate the flow of questions and answers realistically (including responding "we don't have that information"--that intelligence is not in his "dream"). Clearly, it is not going to be possible to Monte Carlo all the possible branchings at this level of definition. It is probably alright if part of the sequence is the resource expert's modal enrichment of other parts which are selected probabilistically. Another case where the technique of step-through needs developing.

6.3 We were not able to identify any specific place where the expert had knowledge that the trainee lacked, at least which would have made a tangible difference. It may not be significant that it was not articulated. It may

still be there. A major part of the learning is not knowledge but patterns of behavior, e.g., working the system harder than you were trained to.

6.4 We are really ending up with an annotated case study which is hypothetical. Not a good test of step-through.

6.5 A map exercise with interruptions might be a better case study approach to learning, but still not quite the same as the Harvard case study method. It is addressing a different purpose from step-through.

6.6 Whether in the step-through or case study mode, military expertise is needed for three roles: the expert whose knowledge is being elicited, the source of scenario data, and the elicitor. Lack of expertise impaired our ability to do the latter. If we are trying to determine the "expert's increment" the suggestion is run the exercise twice, once with a trainee and once with an expert, and examine the difference.

6.7 It seems clear that the kind of knowledge we are going after here is *not* susceptible to machine coding, and therefore should probably not be pursued. EW is confirming this. What can be handled at a computer workstation is probably low level data or perhaps doctrine retrieval, rather than the more sophisticated interpretation we are getting at here.

6.8 If a suitable scenario exists, it would serve training purposes, but it is not clear if this is relevant to generating a computerizable product, which now seems called for.

6.9 More generally, it raises the question which *is* relevant to the project: how is the expert's knowledge structured? In particular, is it high or low level rules? Marvin is suggesting, I think, that it could be tested empirically. If it is low level, you will produce it quickly; but may not be able to adapt so readily to a new situation. I read the evidence in this elicitation session as indicating rather low level rules. Perhaps that is because we are in a situation familiar to him. In a more unusual situation, e.g., nuclear, he might call up higher level rules. More than one structure may exist in his head to be accessed in different circumstances.

6.10 An important suggestion that we are getting some high level rules, because we don't have a current expert, one whose knowledge we really want to elicit.

6.11 If we are using step-through as a training case study, everything except specific function being trained (G-2) is treated as " the outside world," e.g., it includes the actions of underlings he has to implement his directives.

6.12 Important distinction between the knowledge of a teacher and the knowledge of a doer.

7.0 KNOWLEDGE STRUCTURE

7.1 The knowledge structure John Leddo is eliciting appears to be a top-down structure, with mission accomplishment at the top. (He developed a structure on paper, as he proceeded.) I suppose it would generalize into some kind of

influence diagram. This is clearly a relevant kind of knowledge which can be largely decoupled from specific inference and decision tasks. Its value will also persist (at least its structure) from day to day and perhaps battle to battle.

A possible computerized function, involving this knowledge, would be a probabilistic model of key elements in the battlefield, which have default values which can be overridden and updated. Particularly as you are unlikely to have a methodological expert to work the system, at division level. The place to start this sort of thing is surely back in the Pentagon, rather than out in the field.

Another possibility would be a computerized piece of doctrine perhaps specialized to a class of situations like the Fulda gap. The division will probably not have the necessary resources or the elapsed time to use such an aid.

7.2 We are picking up different bits of war lore illustrated in the context of Treysa defense.

7.3 On its face value, EW appears to be saying that in advan e of World War III starting, almost everything worth knowing is in doctrine, i.e., there is no significant real world experience beyond that.

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ATTACHMENT A-3: SESSION GROUNDRULES

MEMORANDUM

TO: Knowledge Elicitation Project Team

FROM: Rex V. Brown

SUBJECT: Elicitation Working Session

DATE: November 21, 1986

GROUND RULES FOR MONDAY'S WORKING SESSION

The Elicitation Task

We will be taking a trial run at a knowledge elicitation task specified as follows.

The knowledge to be elicited is what General Whitehead knows which he would want to put at the disposal of a less experienced 35A (military occupational specialty), who is preparing to take up the post of divisional G-2 in the Ft. Leavenworth "time stress" scenario at the time in question.

Knowledge is limited to that which is not available in existing publications, nor routinely learned at a junior school such as at Ft. Leavenworth. It may include: knowledge which is situation specific (i.e., as regards geography, threat, mission, etc.); is too new or controversial to be embodied in existing documents; organizationally sensitive (such as using discretion in "jumping channels"); goes beyond general doctrine (e.g., in handling exceptions or generating conditional decision rules).

To limit the scope of the knowledge further, we will focus on certain separable issues, within the more general area of intelligence collection management, and will also limit ourselves to action guidance (as contrasted with description or causal generalization).

We may need to fine tune, on the spot, a still finer definition of knowledge

One is to use the same task and subject but try out, more deliberately, specific techniques and intellectual structures. Another would be to repeat to try a slightly different task on basically the same subject and subject matter, for example changing the assumption about who is to be the receiver of the elicited information and how (e.g., a computerized expert system) or purpose (e.g., the evaluation of training rather than training, itself or communication between expert). Alternatively, we could try a different type of subject matter with the same or different subject (e.g., descriptive or causal knowledge rather than action guidance, which I think this one will be).

In any case we will want to step back and think what if anything we have learned from this small data point which might influence the general conduct of the project.

ATTACHMENT A-4: INITIAL STATEMENT OF KNOWLEDGE

Memo For: New Division G-2
From Ennis Whitehead
Date: November 27, 1986
Subject: Some Suggestions for Your New Undertaking

1. Use the basics from your training and previous experience

o knowledge of intelligence process, organization, system, SOPs, forms, etc.

o Knowledge of enemy: organization,doctrine, weapons, capabilities, perceived strengths and weaknesses

o knowledge of collection resources and capabilities: within division, higher echelon, adjacent (US and foreign), complementary resources controlled by others (G3, Eng, FA, etc)

o knowledge of counterintelligence

o understand how to make the system work (formal and informal).

o understand how to use people (this is not a one man expert system)

o develop and train subordinates

2. Adapt the basics to the wartime situation.

o relate prior knowledge to current situation

o anticipate and interpret commander's needs and guidance; think ahead 24 to 48 hours or longer(not done in this example).

o focus on the important; prioritze the intelligence effort

o identify and discard erroneous perceptions and knowledge; adapt quickly to reality of situation

o use all collection means to gain information (example: use Bundespost to call behind enemy [illegible] to learn what is happening; interview German border guards and local officials escaping from captured areas).

o meet and assess key players in the division intell operation (own staff, Bde S2s, Artillery, Aviation, corps G2 staff, adjacent intell staffs); get rid of incompetents quickly; find the quality people.

o establish a good informal commo system; direct contact is needed to put flesh on bones of periodic intell reports, etc

o give attention to detail; this is a detail business with an over abundance of fragments of information; create a system which provides the mechanism for handling detail; check it periodically to see if it is working, but don't get lost in the detail yourself.

o seek advice; keep an open mind; challenge your perceptions and assumptions; challenge the assumptions and perceptions of others (commander, G3, etc).

o remember that almost all incoming reports are estimates or judgemental deductions based on limited information and inexperienced (first days of war) personnel, often transmitted in haste, under pressure.

o Verify peacetime perceptions of enemy tactics, weapons, capabilities, concerns; for example, are E. German or Polish forces being used? which of our weapon systems are most effective; how to does the enemy find its counterbattery targets (Sigint, radar, airborne artillery observers, etc).

o Make sure the flash reporting system works so that critical information is gotten to the commander and G3 quickly.

o Timeliness is more critical that total accuracy; G2's judgement can compensate for accuracy, but not for timliness.

3. Comments on Current Intel Summary

o Inability of MRDs to continue attack is based on supply problem while their combat capability is relatively unimpaired; how do we know the supply problem is real? Remember there is a one to four hours lag in information from the frontline units. I would have estimated that the two MRDs would continue their attacks and the 9TD could be attacking through one of them right now(0600). Otherwise why would that division come within artillery range, unless it was about to pass through and continue the attack. Also the second echelon 7TA is so close that it could also be moving forward to attack after topping off its vehicles (a temporary stop outside artillery range to make final preparations).

o The above comments lead me to set these high priority collection requirements for everyone who has a capability to provide some indication:

-Is the 9TD moving; are there any indications that it will attack within the next 2, 4, 8, 12 or 24 hours? (Commander may be influenced in his course of action if he knew the answer to that question).

-Report any indications of attack preparations or forward movement of 7TA; Are there any indications where and when it will attack in next 4, 8, 12. 24 hours? Indicators may include -------.

-Report any information or indicators that nuclear weapons may be used

-Watch the north flank and the boundary with the 23d Panzer Division. Corps and national boundaries are desirable attack points; send an experienced officer to the German CP to get a good update; establish a special intell liaison team with commo if it does not already exist.

ATTACHMENT A-5: SUMMARY (KBL)

ROUGH NOTES ON KNOWLEDGE ELICITATION SESSION

24 NOVEMBER 1986

(KBL)

[The following are some rough notes on Monday's knowledge elicitation session with General Whitehead. I've mostly just tried to chronicle the session as it happened. Although some long dialogues just have the main points summarized, the notes basically follow the flow of the session. Contributors are identified by their initials. Anything inside square brackets is my editorial comment. My summary follows the discussion.]

RVB began by setting context. Rapid pass at sample elicitation. Context is training of new G2 fresh out of school. EW to take role of seasoned G2 trying to impart his wisdom. Specifically, to concentrate on getting across info that wouldn't be learned in school. Problem focus is information collection management.

The schedule was:

1. General flailing about, getting feel for problem.

2. Focus on a specific problem: method for tasking specific sub-units & intel assets to locate enemy command posts.

3. A more directed elicitation, to be directed & focused by RVB.

4. Open to audience to try out other methods.

1. <u>General. Feel for problem.</u>

RVB began by asking for any general nuggets of wisdom, before moving into Fulda Gap scenario. EW responded: <u>(1) G2's problem is to adapt what's learned in training to real life wartime situation; (2) more than just knowledge is involved--must understand how to use people.</u>

EW then jumped into scenario. Wouldn't trust previous G2's assessment because of conflict betw. reports (9th TD stationary; 7TA not attacking) & Red doctrine (don't sit within artillery range; 7TA is 50 km out, but doctrine says reserve sits at 100 km). Also, doctrine & history say it's good to attack on boundary, especially between nat'l forces. Takes report 4 hrs to get to us, and they may have started moving in that time. Would send someone up

to 23rd Panzer to eyeball situation.

General tenets:

- o Think further ahead than the current battle. 24-48 hours out.
- o Learn to use all intel resources, both under your control and not.
- o Don't accept assumptions of intel report. All info is based on estimates. Challenge. Try to confirm.
- o Speed (get info to cmdr) more impt than accuracy, but give judgment [if you're not sure, give indication of uncertainty?].

[Note: EW seemed to be more able to articulate these general tenets in the context of the example. RVB's instructions were to give general wisdom before example; EW jumped to example, then generalized. This happened repeatedly during the session.]

2. <u>Tasking subunits: CP location</u>

EW said this was not the G2's problem. He is more interested in what enemy units are doing. Where CP is located is secondary. This sub-problem was basically dropped from that point on.

2a. <u>Collecting information on enemy movement</u>

EW clearly thought the most important problem was finding out whether 9TD and 7TA were moving in to attack, and where. He started listing resources that could be used for finding this out. Use Corps assets (Mohawks, communications intercept); ask division ELINT people to look for radar indicative of movement.

There ensued some questions relating to how he decided which information collection was a priority. RVB: how would he transmit this to G2 so he could replicate?

EW: <u>Major consideration: what is most serious threat to division?</u> [He kept coming back to this point--his overall strategy seemed to be to try to collect more info on most serious potential threat.] We can handle guys attacking now, but not 9TD (1 hr away) or big force in rear (4-6 hrs away & 5x our strength). The earlier I can give hard info to cmdr, the earlier he can move

to meet it. He can tell higher HQ & get their reserve, but takes hours to get them here, so need info before need is critical.

CC: How do you know which info to question & which to accept? Are certain sources assumed to be "hard data" and others assumptions; you believe hard data & not assumptions?

EW: Used judgment to assume 9TD had been located. [Later said map would have ?'s unless data were very good; this ID was unusually precise for military map. Indicative of very good information.] Hedged, maybe that was hasty assumption. Again noted highest collection priority should be greatest threat to div.

Next were some comments on methodology: RVB: candidate - recreate scenario in presence of expert. EW: need knowledge expert to pick up anything elicitors have missed.

Dialogue between CC & EW: need to narrow possible Red capabilities into few manageable CA's. EW listed a few (continue attack; commit 9TD; move up 7TA). Always worried about unknown forces. Nuclear, threat in rear. Didn't answer Q about whether that means you shouldn't commit everything.

RVB: does EW just have heuristics about what kind of knowledge is needed, or does it derive from loss associated with doing it wrong? Is knowledge organized around valuable items of info or actions predicated on info (esp. how actions & therefore consequences would change if we had the info)? EW reiterated: worry about greatest threat to accomplishment of mission; time is crucial. [This seems to imply loss-driven--except what if there's nothing we can do if greatest threat materializes? Unfortunately, we didn't ask him that.]

Dialogue in which TM asked how much of task was role playing. EW: much of it. Need to be sensitive to how war (now) is different from peacetime exercises. Again noted conflict betw. doctrine & report that 9TD not moving.

CC: is reporting cmdr specific? EW: cmdrs are different. Some get into G2 task, have "sense" of battlefield. [Never really said whether he'd report differently to the 2 types.]

RVB: what will G2 do better if he absorbs your lessons? EW: Hard question.

- o Prioritize. Spot check detailed info, but concentrate on hi priority things.
- o Take full advantage of resources.

Doesn't know whether there are gaps in knowledge of G2 fresh out of Lev. Intuition is yes. TM: you concentrated on sources of uncertainty. Any you might not anticipate from training? EW: again commented on conflict betw. doctrine & intel report 9TD stationary.

MSC: You observe a conflict betw doctrine & report, and want to find out more info. What do you do if you can't get more info? EW responded by listing other sources of information. MSC said assume all sources are down. EW said if there were movement you'd be able to find out. If no evidence of movement, he'd tell cmdr they weren't moving. Would include a measure of his uncertainty.

3. Structured approach

Proceed to a step through simulation. EW was asked to "play" out the scenario, both making decisions & imagining events unfolding. [If we were to do this for real, we'd want different people playing different parts. Perhaps an expert, a greenhorn G2, and someone to generate events--all different people.] Context: 4 hrs have elapsed & cmdr has decided on CA3 (the balanced one). Time is 1000 hrs & we're now implementing CA3 [implicit assumption that no new information, esp. about movement of 9TD or 7TA, has occurred].

EW says cmdr will withdraw some of BDE forces to build reserve; that will be done now, in daylight (assuming they can be reasonably safe from air attacks).

EW: too late for G2 to contribute much towards what's happening right now. He should have antennae out, looking 24 hrs ahead. Sensitize analysts to need to give info quickly.

Asked to generate continuation of events, EW gives several possibilities (Red continues attack; Red moves 9TD up. If second, we should get indications--radio traffic & other signatures--there are 1000 vehicles.)

Assume 9TA attacks @ 1000 hrs, in center. Boundary of the 2 BDEs. Passing thru 1st echelon could take 1-20 hrs. Key problem is finding out where is main attack--you would soon know where you were taking the heaviest attack.

RVB: what about them fooling us with a small attack @ wrong place to get us to commit? EW: you would expect that if attack lines had stabilized. They've been steadily moving forward, so it's less likely. In general, all the Red forces have order to carry out secondary attack, but attack will be heavier @ location of primary attack. Purpose of secondary attack:

- o confuse you
- o hold your forces in place.

You will know soon where main attack is.

Assume only penetration is one area. G2's job: make sure you're not being fooled. Don't want premature commitment of reserve. Goal: find out who's in main attack. Info sources: radio (at least, you can find out # of nets up), prisoners. Ask your forces to continue concentrating on 9th. Most of your collection resources are with BDEs. If lost, try to replace them.

RVB: what might bad G2 do? EW: [didn't really answer question] Need to adapt system. RVB: example? EW: ask for:

- o AVN BDE's Scout helicopters (tell you size of penetration)
- o Artillery (to locate their artillery. Signals/trajectory)
- o Additional surveillance resources from Corps
- o Might want G-3 to establish recon & surv. mission. Find out where enemy might be going. Use air cavalry SQN of reserve. (G3 might not go along if low on helicopters, needs them to fight. Can't have too many flying hrs.)

General situation: attack heavier than previously. Led us to believe 9TD attacking. Division is responding. EW wants to know what 9TD is doing. Also watching 7TA.

What if later, 9TD attacks on north flank? Earlier attack was secondary. Then you would have to shift resources. Adjust your own easily adjustable collection resources.

- o CO of surv radars (1 PLT each BDE)--*not* easily movable.
- o 3 helicopters to collect ELINT (radar) signals. Put them up.

- Very quickly, move ground based collection centers up north.
- Ask for help from Corps.

Things you would have done earlier to hedge against this possibility:

- You would have been talking to Corps all along. Maybe he would have had tipoff earlier & let you know.
- You would have gone up to talk with Germans. (Certainly use secure phone if you had it.) You would take along someone trusted who knew German.
- Would have kept some helicopters down (they're scarce resource. Limited flying hours, & can get shot down. So don't use them all up in one place.)

Mid afternoon now.

Generalities: In school you learn enemy capabilities & limitations. There are rules of thumb [I don't know whether he meant you learn the rules of thumb in school or you get them later on the job]. G2 is always working off limited info & can never give perfect estimates. Battle of bulge: refused to interpret what they saw in way Germans actually were deploying their forces. [Was this an admonition to keep an open mind? Not to take school learning about their doctrine too literally?]

Again, a discussion about what EW might do/know different from greenhorn. [Problem: EW doesn't know, and we have no baseline for comparison.] JL noted that EW's approach was very different from S's in Leavenworth experiment--he focuses on general strategic issues, they on micro detail. EW noted this could be because they were G3's. (But shouldn't the G3's be the ones concerned with strategy?) EW has learned: (1) Drive system 110% [this is repeatedly stressed--I'm not sure of an operational meaning]; (2) Aircraft are scarce resource; don't use frivolously [is this a qualification to (1)?].

CC noted that much of EW's knowledge seemed to be expressible only thru doing--he doesn't have access to it @ level of verbalization. CW expressed concern that verbalization could be wrong--e.g. teacher teaches differently than he acts, for reasons of pedagogy.

4. Open session

JL takes over. Asks: You've given us overall structure: important to find out

o Where is enemy?

o What can he do?

Why does this matter?

EW: looking for threats to accomplishment of overall mission. Top-level goal: find out info about threats to current mission. Secondary goal: retain ability to perform next mission.

To accomplish this, (1) describe to cmdr: what are greatest threats impacting on his mission; (2) tell him what enemy's going to do near term & long term (long term - 24-48 hrs in Europe; months in Vietnam).

To find out what threats are, you look at forces, terrain, weather. [METT-T] If Red had AF, would look at it too. Look @ forces in terms of force ratios. [Note that this is only second time he's explicitly mentioned force ratios. Recall earlier he said 7TA was 5x our strength.] Force ratios usually just match div for div, but should have mobility, capability (firepower), previous practices (agression) factored in somewhere. G2 does enemy, G3 does friendly [I assume with help of G1], force ratio is computed jointly. Look @ long term threats: size, distance, capability to initiate attack.

JL: how to decide on capability to attack? EW: Force ratio: doctrine says we can defend 3:1. He'd like 6:1 to attack. Speculates about utility of designing workstation to improve our ability to do these computations.

JL: How to determine distance constituting a threat? EW: Road network, how long to travel [this would factor in both speed & equipment], doctrine. Road network: does it permit diversion? Distance, location, terrain: can they get to you? Standard [doctrinal] rates of march--you can compute time to move. Taught in book. Doctrine says division worries 24-48 hrs ahead.

JL: Capability to initiate attack? [He asked this before.]

EW: Force ratio. [Same answer as before]. Plus what they've been doing,

e.g. attacking plus reserve moving up. Reserve plus guys on line.

JL: Look at map & tell me what are greatest threats to you.

EW: Worst case, they have fuel & orders; ready to move. Calculate time to 1st place they could attack, looking @ road net. 80 km @ 20 km/hr. Might be @ pt of contact in 4 hrs. If they need to break into contact formation & fuel up it would be 8-12 hrs. Might take advantage [of what?], attack 1st light tomorrow AM. Or could come late PM.

AM gives you:

- o more time for recon
- o easier passage of guard for reserves who've never seen this battlefield
- o need more time; could have air support, artillery support

Better surprise at night. Doctrine supports: better prep AM; better surprise PM [this generalization was prompted by JL].

JL: tell us more about factors contributing to success of attack. EW started wargaming as if he were enemy cmdr: if I can move div column 40 km at night (if I don't get stuck) then maneuver means everything. If I can't make breakthrough of crust, then I want to line up everything. Options: (1) hasty night attack; (2) move troops to forw assembly area; recon; attack 1st AM light.

There followed a discussion of how EW had taken a high-level question (factors contributing to success of attack) & responded with low-level generation of for-instance. It was noted that EW was less comfortable just <u>stating</u> general principles; more comfortable <u>illustrating</u> them first by example, then (sometimes with prompting from elicitors) abstracting general principles. EW: you want general principles? 9 Principles of War. Then admitted he couldn't even list them all; certainly does not organize knowledge by them.

EW then abstracted: criterion of successful attack: Be on objective. [This does not to me seem to be a natural generalization of the above example, except at some remove: Overall goal = be on objective. Means to that goal are surprise & being well prepared. PM attack supports 1st; AM attack supports 2nd. So you have to think about how Red will weigh & trade off.]

[The following is an attempt to summarize some of the main points of the discussion.

Overall objectives of G2 (order of priority):

1. Identify greatest potential threats to mission accomplishment.
2. Retain ability to perform next mission.

To do this: <u>Remember, all info is uncertain</u>.

Sub-goals:

a. Prioritize greatest info needs.
b. Try to collect info about hi priority items.
c. Give commander prompt (even if incomplete) info while doing b.

To do a:

i. Most important problem: where is he & what is he doing?

ii. Where do you suspect your info is *wrong or incomplete*?
   - o Where Red doctrine conflicts with your intel estimates
   - o You know something about which sources are usually reliable
   - o There is a standard G2 language used on maps that tells you how good your info is. (i.e. ? if ID/location is uncertain)

iii. Which area of uncertainty/incompleteness has most serious consequences?
   - o Enemy capability
     - Size
     - Distance (converts to time)
       - x Road network
       - x Capability of Red units to move
       - x Doctrine
     - Capability to attack.
       - x Force ratio
       - x Practices (agression)
       - x Capabilities (firepower)
   - o Factors influencing successful attack
     - Surprise
     - Preparation

x Recon

x Support: Air & Artillery

- Objective

iv. Look 24-48 hrs into future.

v. Keep an open mind & be ready to act if events disconfirm your hypotheses

To do b:

i. Use all your resources 110%

o Assets under your direct control

o Corps assets

x Keep in contact with Corps

x Give them specific requests

o International: keep in touch with Germans

ii. Take account of limitations, scarce resources.

o Flying hrs limited, can lose helicopters/planes.

o Don't overcommit; hedge against unexpected.

x Keep some reserve, esp. on forces that can't be moved quickly.

iii. Spot check details, but don't get enmeshed in them.

To do c:

i. Give cmdr your best current estimate.

ii. Give him your best judgment

o Where you are uncertain

o What consequences could be if you're wrong

Notes on elicitation methodology:

o There seemed to be some concern that it was too unfocused, too general. That we weren't getting anything useful. Others thought that we were getting a lot.

- It is pretty clear that General Whitehead's knowledge is more accessible at the detail level than at the level of stating general principles out of context. If this generalizes, it has clear implications for the methodology we use.

- It was agreed that a good candidate method would be to observe a map exercise and be allowed to stop and ask questions at any point. Observing the map exercise at Leavenworth will not be good enough because we can't ask questions, but it will give us useful information that will help us to ask good questions the next time.

- It was also generally agreed that we need a structural template to fit what we're getting into. (Of course, you need sessions like this one to help you develop your structure.) John says he's well on the way to developing a structure. I think <u>soon</u> we should have a meeting at which he presents his preliminary ideas for group feedback.

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ATTACHMENT A-6: SUBJECT'S RESPONSE

TO: Rex Brown, DSC

FROM: Ennis Whitehead, BAL (in haste) Ennis

DATE: November 26, 1986

SUBJECT: Comments on Trial Session

I thought the session was very useful. It showed that a simple map exercise or case study can provide the medium for trying out several elicitation methodologies. In fact, it may become our principal model, because it is so well understood by military officers. On the other hand, we also need to use other approaches to broaden the total project.

Three comments on the session.

- What knowledge are we trying to elicit? Facts? Conceptualizations? Estimating rules? Procedures? Integrating methodologies? We need to define "knowledge" better.

- How many data points do we need? I believe BAL and the Army school system are the best sources.

- Where are we headed? We need to find a "purpose" for developing elicitation methodologies. We cannot afford to avoid that issue very long.

I thought John Leddo was very well prepared with his line of questioning. I assume that all "elicitations" will be equally well prepared when we go into data collection.

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ATTACHMENT A-7: MODERATOR'S PERSPECTIVE

MEMORANDUM

TO: Knowledge Elicitation Project Team

FROM: Rex V. Brown RVB

SUBJECT: Trialcase Exercise

DATE: December 5, 1986

REFLECTIONS ON SESSION WITH GENERAL WHITEHEAD

The following are thoughts on some of the issues I had hoped the trial elicitation session would cast light on, for project planning purposes. Due to the very tentative and exploratory nature of the session and the fact that only one subject and one possible elicitation task was addressed, inclusions can only be suggestive and impressionistic.

Type of Elicitation Task(s) We Should be Developing Methods For

We were testing a very limited kind of elicitation task: the knowledge an expert G-2 would want a trained but inexperienced G-2 to know, on taking up a divisional G-2 assignment, in the early stages of hostilities with the Soviets in West Germany. If the case we took is at all representative, while it is clear that an expert would have a great deal to contribute to the trainee (beyond what the trainee would have picked up in regular school), it is not obvious that the best way to do it is along the lines we were exploring. I.e., extracting the knowledge, and recording it somehow (e.g., in text, video or computer), with a view to getting it into the trainee later. The alternative, of having the expert interact with the trainee directly (e.g., in a pre-posting briefing), might be outside our scope.

I am not suggesting we give up on the training function. It does seem clear to me, however, that the selection of knowledge to be elicited is highly dependent on the use to which it is to be put (and so is the method for eliciting it). If the purpose is training (as here) knowledge elicitation probably needs to be developed in the context of a broader training philosophy. This again, probably takes us beyond our scope.

Conversely, if we are planning to develop some kind of computerized expert system, to be used as a decision or inference aid on the battlefield, we would develop it in a way that has, I suspect,

little overlap with the training function. Knowledge elicitation for trainee *evaluation* would probably be quite different again.

In any case, we need to determine what product or products we will eventually try to deliver--i.e., methodologies for what? There is probably nothing wrong with moving out in more than one direction initially, with a view to possibly settling on one later. However, I strongly recommend getting feedback, if not direction, from the "client." Discussion with some key people at Huachuca would be very helpful.

<u>What Kinds of Knowledge do we want to be able to Elicit</u>

The underlying *thrust* of the knowledge EW was giving us was of the production rule type e.g., "if the enemy reserves are within artillery range they are probably on the move"; "other things being equal, the enemy will probably attack at the boundary between friendly forces." Much of the knowledge, as in those two examples, was on the *inferences* that would go into a G-2's decisions, rather than directly as *decision rules*. This would make sense, since you can be more sure of inferences than of decisions which take those inferences into account, and also take into account a whole lot of other things that EW would not know about (at least from the amount of background information he has been given).

Much of his knowledge would be relevant to producing enhanced doctrinal documents (such as field manuals), but the form he gave the knowledge in, was almost invariably very situation specific, i.e., not even as general as a production rule. If we probe into why he made these recommendations, we can no doubt work our way up to the goals--means hierarchy (and that might be a useful exercise to pursue).

There seem to be two distinctive types of knowledge we uncovered which is *not* in your normal field manual material: illustrative, situation specific knowledge which *implies* more general principles; and *considerations* to take into account when coming up with specific inferences or actions, though the latter presumably would be in the manuals, if anyone thought they were relevant.

A promising body of knowledge to be elicited would be a series of battle sequences, whose function is to give trainees vicarious, concentrated battle experience, to complement what they get out of manuals. The enemy and non G-2 friendly components would be made plausible (but not otherwise explained); and the G-2 components would represent the expert's best judgment, (with

a commentary supplied by him.) Alternatively, if available, real war sequences could be used, with the actual (not necessarily best) G-2 action. Here the expert's contribution could be limited to *commentary* on that G-2 action. Where in the interpretative--generative continuum the commentary would be pitched depends not only on how the expert thinks, but how the trainee thinks too.

If the latter type of knowledge is being elicited, it might be put in the form of training materials e.g., texts or video--but interaction with the trainee could be computer-aided.

Developing the Step-through Approach to Elicitation

Some variant of *step-through* simulation (itself a variant of wargaming) looks promising, but the tack I took would need major modifications. Most important, in particular, the team generating the non G-2 sequence, needs to be distinct from the expert generating the G-2 responses of primary interest. (For example, enemy action might be modeled by another G-2 expert, friendly action by G-3 etc.) At this point there are economy and deluxe options to step-through.

The economy model would be static pre-existing (and therefore and cheaply available) sequences, are) be presented to the expert, who says at each G-2 action node what he would have done and why. However, the sequence would then continue assuming that the *pre-existing* G-2 action written into the sequence was the one adopted. That pre-specified G-2 action would be handled in no more detail than any other item in the sequence.

The deluxe option, the real step-through version, has the expert's G-2 input integrated into the sequence. I.e., the "response team" and the expert would alternate taking into account everything that has gone before. In this way, we could simulate what the result of the G-2 action was, with particular attention to what difference it made.

What Next?

If it turns out that the client wants (and is to be given) methods for eliciting *this* type of knowledge, then I suggest we try to put the deluxe option into practice. I see no reason not to stick with the Treysa defense scenario since we are relatively up to speed on it. For this we would need to establish a "response team", probably one or two more from BAL's staff. We would allow the expert to ask the response team to invent realistically any information they had not already volunteered, but which the real G-2 would have access to and comment on why he

did what he did. Ideally the response team would specify the "bottom line" of how the engagement turned out, picking out anything of special relevance to the G-2 (for example, if any controversial decisions which he made were, or were not, vindicated by the outcome of the battle). Our view of knowledge structures, mental models, etc. may influence (or be influenced by) the unfolding of this experiment.

If not this, What?

Whether we pursue this tack, depends not only on the client's expressions of interest, but also on ours. I.e., if we don't go after this type of product what *will* we go after? Probably it makes sense to test the waters for a computer based expert system, without delay, if that is the most promising alternative. I would recommend that Craig Cook or his colleagues try to scope out such an exercise (again, perhaps, using a trialcase exercise) to the point where we can visualize what the products might look like (and for what purpose).

We can seek closure after the Huachaca meeting.

ATTACHMENT A-8: EXPERT SYSTEM PERSPECTIVE

MEMORANDUM

TO: Rex Brown

FROM: Craig Cook

SUBJECT: Observations on Trial Knowledge Elicitation Session - 11/24/86

DATE: December 8, 1986

The following are some observations and ideas about what transpired at the Subject trial session and how it might influence the direction of the project. The purpose of this memo is to log these various points for future discussion/consideration.

The session seemed useful in opening up the topic area (Management of Tactical Intelligence Collection). Several categories of knowledge were identified - primarily by example. Considerable analysis and follow-up sessions presumably would be required to structure the knowledge, complete the identification of the components in each category, and build the appropriate associations and chains of reasoning before we could claim to have successfully elicited useful knowledge.

A major issue in any elicitation endeavor would seem to be "What knowledge is being sought?" This is tied to the question of how much knowledge the novice G2 can be reasonably expected to have a priori. This "basic knowledge" is, itself, a fuzzy set since it will entail not only formal training but the experience and intuition of the G2 and therefore vary by individual. Hence, an initial give-and-take question and answer interchange may be necessary in any session so that the expert can determine what knowledge (and at what level of detail) it is necessary to impart.

In this particular session, there was no novice G2 for the expert to probe; hence, there was some difficulty for the expert in deciding how much to say in a response. Further, because we as elicitors, did not have a broad base of knowledge in the application, we are unable to assess the quality or utility of the knowledge provided.

A related shortcoming of the trial session involved its incompleteness. By establishing a scenario that was all hypothetical we asked the expert to make many assumptions:

- Assume there is a novice G2
- Assume he has some gaps in his knowledge
- Guess what you (the expert) think those gaps would be
- Assume the wartime scenario is as given
- Indicate what actions you would take
- Assume what responses you would get
- Indicate what intelligence collection resources you might have available
- Guess what might go wrong
- With all this, determine what the enemy's plans are (which is unverifiable since the scenario is incomplete).

This kind of open-ended situation would *seem* to be useful for getting the expert to identify many potentially relevant pieces of knowledge, i.e., breadth. However, it seems inadequate for eliciting subtle distinctions that contribute to the expert's expertise (over that of a novice G2).

In the session as it transpired the elicitors did not generate especially sophisticated questions designed to elicit subtleties in the expert's knowledge. One result of this may be to have given the expert the impression that the elicitors did not know enough to question the validity of what the expert was saying. Thus there may not have been sufficient pressure on the expert to generate high-quality knowledge (i.e., knowledge which would withstand peer review). I suspect that any expert would insist on the right to review/revise the knowledge prior to submitting it for peer review.

The second round, John's top-down structured interview approach, seemed to elicit specific detail (e.g., lists). However, the responses to direct questions also seemed to be direct answers which may or may not have been well thought-out. There appeared to be some motivation for responding with a quick and short answer. The more fundamental questions, i.e., those with textbook like answers seemed to be slightly irritating to the expert (e.g., answers like "its straight out of the book."). This may imply the need to do adequate preparation so that basic knowledge questions are avoided or at least asked deliberately.

The expert appeared to have vast quantities of knowledge about the domain, but it did not seem to be organized for pedagogical purposes (i.e., structured in any particular way). The expert was best able to impart his knowledge by using examples and then stating some general principle that encompasses the example rather than presenting a theory and listing a set of general principles followed by specific examples. This may be the case with practitioners (vs. teachers) and may need to be accommodated in the methodology.

In summary, there seems to be no clear way to measure the quality of the elicitation session. Assessing the success of a session depends upon the assessor's point of view and might involve a complex trade-off among such issues as:

- Speed of the session
- Volume of data/knowledge obtained
- Richness of knowledge
- Novelty of knowledge (over textbook "basic" knowledge)
- Rapport between elicitor and expert
- Utility of knowledge extracted
- Breadth of knowledge identified
- Depth of knowledge obtained
- Validity or accuracy of knowledge obtained

Perhaps it is not appropriate to try to assess the absolute quality of a single knowledge elicitation session. Since any elicitation endeavor can be expected to involve many sessions (with reviews and repetition) along with off-line analysis, perhaps it is better to assess the total progress (quality) of the elicitation series and establish specific goals for individual sessions (e.g., "This session will open up as many aspects of the total problem as possible." "This session will concentrate on distinguising the factors which led to this particular decision or choice." etc.). The thing we may want to do is measure the quality of the knowledge base developed to date, identify gaps in it, develop a plan for filling those gaps, and iterate. The measure of quality/success for a particular elicitation session, then, deals with how well the session filled the knowledge gaps (including identifying new gaps).

WORKING PAPER

TO: Rex Brown

FROM: Craig Cook

SUBJECT: Some Thoughts on Knowledge Elicitation

DATE: December 8, 1986

The following are some sketchy ideas that might be worth developing in greater detail.

1. KNOWLEDGE ELICITATION

Knowledge acquisition is the process of obtaining knowledge from a variety of sources and representing it in some form for automated processing.

Knowledge elicitation is the process of soliciting and capturing knowledge from a human source. The process is proactive, cognitive, often iterative, and one which seeks to optimize the utility of the knowledge elicited.

Knowledge elicitation is a two-way communication process. It is more than mere rote recording of the knowledge provided by the source. It entails an active concept formation process on the part of the elicitor which involves data and relationships, procedures and techniques, and values and heuristics.

A key component of knowledge elicitation is the formation of questions, the answers to which are intended to help clarify the distinction among various domain concepts and the reason for various decisions or choices made by the source. In this sense, negative information (i.e., what a concept excludes) can be just as valuable as positive examples in refining the definition of a particular concept.

The quality of a knowledge elicitation endeavor can be measured in several ways:

- Efficiency - The speed with which knowledge is transferred from the source to some medium by the elicitor (including repetitions, restarts, and refinements).
- Effectiveness - The breadth and depth of detail of the knowledge that is captured (i.e., completeness, precision, relevance) as compared to the purpose of the elicitation.

- Usefulness - The accuracy, richness, consistency, or utility of the knowledge obtained through the elicitation.

The quality of a knowledge elicitation endeavor may be influenced by several factors, including:

- The quality of the knowledge source (depth of understanding, breadth of related knowledge, identification of critical issues, clarity, structuredness, etc.)
- The articulateness of the knowledge source for expressing the knowledge in a comprehensible form
- The quality of the techniques employed by the elicitor to draw out and clarify the knowledge
- The skill of the elicitor in employing those techniques and in using the right technique at the right time
- The appropriateness of the medium used to convey the knowledge to the elicitor (e.g., voice, writing, pictures/diagrams, performance of a task)
- The appropriateness of the medium used by the elicitor to capture the knowledge for further analysis, processing, or training
- The breadth, depth, and sophistication of the knowledge already possessed by the elicitor (e.g., familiarity with terminology, background concepts, classic examples)
- The insightfulness of the elicitor and his/her ability to rapidly see patterns or grasp new concepts
- The discipline of the elicitor to avoid drawing hasty conclusions, making unfounded assumptions, or failing to balance breadth and depth appropriately

2. KNOWLEDGE TAXONOMY

The question of "what is knowledge" is a major philosophical area probably not relevant to our project. However, the question of "what knowledge are we eliciting" seems to be pertinent to directing the elicitation process. Three broad schemes for categorizing knowledge are:

- Epistomological - By subject area
- Representational - By how it is represented
- Utilitarian - By its use

The epistomological approach is characterized by models such as academic disciplines at a university or the Dewey Decimal System employed by library science. The representational approach is characterized by such aspects as mental vs. written, textual vs. pictorial, structured vs. unstructured, associative vs. logical.

The utilitarian model categorizes knowledge into three broad categories according to how the knowlege is used (not what it is about nor how it is represented in some medium):

(1) Factual Knowledge - Descriptive knowledge pertaining to real or conceptual objects. For example,

- Data
- Relationships
- Pictures/Diagrams
- Narrative Text

(2) Procedural Knowledge - Knowledge which is, in some sense, executable. For example,

- Procedures
- Algorithms
- Skills
- Perception

(3) Judgmental Knowledge - Evaluative knowledge which influences choices, decisions, or preferences. For example,

- Values
- Goals
- Objectives
- Constraints

Factual knowledge (whether true or false or unverified) is what the source knows. Procedural knowledge is what the source knows how to do (however adept or inept). Judgmental knowledge deals with understanding why a particular piece of knowledge is important.

Knowledge elicitation involves capturing the knowledge in some form which can be replicated later. This knowledge may be stored in the head of the elicitor or it may be written down in some other medium. Knowledge representation deals with how knowledge is captured in some medium. Many forms of knowledge representation have been developed, including:

- Textual Descriptions
- Formal Procedures
- Computer Programs
- Mathematics and Logic
- Pictures, Diagrams, and Charts

- Rules of Behavior
- Frames and Data Structures
- Heuristics and Guidelines
- Time Sequenced Scripts
- Neural Networks
- Mental Models

The appropriateness of a knowledge representation depends upon

- What kind of knowledge is being represented (e.g., facts, procedures, judgments)

- To what use the knowledge will be put (e.g., problem-solving, task performance, strategic planning, assessment, training)

- The intellectual capabilites and background of the knowledge interpreter, i.e., the entity which will make use of the knowledge represented (e.g., depth of detail, level of abstraction, breadth of related knowledge, "common sense.")

The selection of a knowledge representation scheme can influence the quality of a knowledge elicitation endeavor by facilitating or hindering the efficiency, effectiveness, and usefulness of the elicitation process. But it is not clear in what ways or by how much the influence could be felt. Also, there may be a series of representation schemes that can be employed and the knowledge may be translated from one to another as needed (in part or in toto).

Tools could be developed to aid the elicitor by

- Quickly capturing the knowledge as it is presented

- Saving the knowledge for subsequent review and analysis

- Regenerating the knowledge for some purpose (e.g., training, explanation, or use)

- Assessing the consistency of the knowledge captured/represented and identifying inconsistencies

- Postulating concepts and generating experiments or questions to refine concept definitions, to test procedural instructions, or to clarify value judgments.

The knowledge possessed or employed by any individual in performing a cognitive function can be extraordinarily large, diverse, and complex. The performance of a substantive task may involve

- The retrieval of facts
- The execution of procedures
- The application of judgments

all occurring concurrently both consciously and subconsciously. The purpose of knowledge elicitation is to draw out this knowledge in some systematic way.

A knowledge source (e.g., a human expert) can easily demonstrate his or her knowledge through the execution of a task (solving a problem, answering a question, manipulating a device, recognizing an object, generating a remark), but when asked to explain (i.e., teach) how the task is done, the source may experience some difficulty. Part of this difficulty may stem from the communication process by which the source must explain the knowledge to the elicitor. This process is generally

- Sequential (vs. a potentially parallel mental activity)

- Slow (vs. the mental speeds with which the source uses the knowledge)

- Structured (vs. a sometimes associative approach).

The process of converting from whatever form the source's mental knowledge may take to a form that is communicable and understandable by the elicitor may impact significantly the quality of the knowledge elicitation endeavor (speed, precision, completeness, clarity, etc.).

3. KNOWLEDGE ELICITATION METHODOLOGY

The purpose of this project is to develop a methodology(ies) for knowledge elicitation. Such a methodology might consist of

- A description of the overall knowledge elicitation process: its goals, its stages, its cycles - and the purpose and issues associated with each

- The identification and description of various techniques for eliciting knowledge from a human source

- An assessment of the appropriateness of the various techniques for eliciting various types of knowledge (where "types" may have several dimensions)

- An indication of the importance of having a representation and the impact it may have on the quality of the elicitation process

- An analysis of various of the knowledge representation schemes and their suitability for various purposes in the knowledge elicitation process

- A means for measuring the quality of the knowledge elicited and of the knowledge elicitation process itself.

The methodologies should have a measure of practical utility, i.e., they should be

- Executable and understandable
- Applicable to several situations
- Identifiable as to when they are/are not applicable
- Measurable as to whether they are working or not.

The methodologies should be couched in terminology/examples that are familiar to the customer (i.e., the U.S. Army) but should be general enough to apply to other domains as well. One criterion that may effect a methodology selection may be the particular Army task or the Army knowledge source.

The methodologies should result in a capturing of knowledge that is suitable for a variety of purposes:

- Training future Army officers
- Evaluating current officers' knowledge
- Developing formal procedures
- Coding a computerized (expert) system.

A major difficulty in eliciting knowledge can be just getting started. If one envisions the source's knowledge as a vast network of highly interconnected nodes with no beginning or end, then there may be no "logical place to start." Probing this network, more or less at random, can provide a potentially large number of paths (associations or lines of reasoning) in many directions leading out from the point of the probe. The job of the elicitor is to steer the session in such a way as to identify the various paths and knowledge chunks so they can be captured (structured, analyzed, used, etc.)

The source is concerned that his or her utterances are meaningful to the elicitor and is unsure of how much detail (or generalization) is necessary for the elicitor to understand the knowledge being expressed. There may be a tendancy to oversimplify (to make it easier for the elicitor to understand or to reduce the amount of work the source must go through to produce the knowledge). For example, the source may espouse "textbook rules" and not go into the details of how exceptions to these rules should be identified or evaluated, or the source may reference other knowledge sources and leave it as "an exercise for the elicitor" to go solicit those sources as well.

The elicitor, at least initially, is faced with a breadth vs. depth issue: how should he/she steer the source through the potentially complex knowledge network and what is the potential impact of that steerage? Should they try to get detail first or

try to form "the big picture" and perhaps establish boundaries to the domain of interest? How much knowledge is "enough" or how much knowledge remains to be elicited? How does the elicitor know when he/she is finished?

It may be that, since both depth and breadth are eventually required, it does not matter in which direction the elicitation process flows but only that it eventually come back to expand along all the different dimensions. Just discovering what those dimensions are could be a major accomplishment of the knowledge eliciation process.

APPENDIX B

ELICITATION MATERIALS USED IN INTERPRETATIVE AND GENERATIVE ELICITATION SESSIONS

APPENDIX B

CONTENTS

CONTENTS (continued)

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B.1 Interpretative Elicitation Forms for:

<u>Scripts</u>:
- Script Identification
- Tracks Listing
- Goals
- Entry Conditions
- Results
- Roles
- Props

<u>Scenes</u>:
- Scene List
- Description
- Actions

<u>Frames</u>:
- Standard Slots
- Additional Slots

<u>Mental Models</u>:
- Context
- Objects
- Forces
- Interactions
- Results

<u>Analogy</u>: Reference/Target

<u>Critical Incident Elicitation</u>:
- Good Cases
- Bad Cases

SCRIPT

EXPERT-ID: ______________________________ **Page** ____ **of** ____

SCRIPT IDENTIFICATION

1. SCRIPT: (description)

SCRIPT-ID: (unique identifier)

SCRIPT

EXPERT-ID: ____ **Page** ____ **of** ____

unique identifier

TRACKS LISTING

2. *How would you describe the [situation development/order of battle] process (and please point out the important differences between them for* *__low-intensity__* vs. *__mid-intensity__* vs. *__high-intensity__* *conflict.*

SCRIPT

EXPERT-ID: ______________________ Page ____ of ____

SCRIPT: ______________________

TRACK: ______________________ GOALS

IF THIS IS THE FIRST TRACK FOR THIS SCRIPT, DO 3a; OTHERWISE JUST REVIEW IT.

3a *In doing the script description, e.g., order of battle/situation development, what exactly is your objective?*

Script Goal(s): Refer to Frame(s):

Refer to M-M(s):

3b *Are there any other objectives besides the most obvious one that you would try to accomplish?*

Track Goal(s): Refer to Frame(s):

Refer to M-M(s):

SCRIPT

EXPERT-ID: ____________________ Page ____ of ____

SCRIPT: ____________________

TRACK: ____________________ ENTRY CONDITIONS

4. *Could you describe under what circumstances other than on order from your commander or when actually in a conflict that you would [begin the process of situation development] [develop an order of battle].*

ENTRY CONDITIONS: Refer to Frame(s):
frame-ids

SCRIPT

EXPERT-ID: ______________________ Page ____ of ____

SCRIPT: ______________________

TRACK: ______________________ RESULTS

5. *What specific results, or outcomes do you expect to get when you follow this procedure? Please describe everything you can think of in the way of "results."*

Results: Refer to Frame(s):

SCRIPT

EXPERT-ID: ________________________________ **Page** ____ **of** ____

SCRIPT: ______________________________

TRACK: ____ ROLES

2. *With whom do you interact and for what purpose?*

Roles: Refer to frame(s):

SCRIPT

EXPERT-ID: ______________________________ **Page** ____ **of** ____

SCRIPT: ______________________________

TRACK: ______________________________ PROPS

3. *What tools (FM's; maps, files, communication devices, automation aids, etc.) do you use? Why are they essential to your job?*

Props: Refer to frame(s):

SCRIPT

EXPERT-ID: ______________________________ Page ____ of ____

SCRIPT: ______________________________

TRACK: ______________________________ SCENE LIST

8. *(ORDER OF BATTLE)*
Without going into a specific case or situation, could you describe the general sequence of actions involved in developing and maintaining an Order of Battle.

(SITUATION DEVELOPMENT)
Without going into a specific case or situation, could you describe the general sequence of actions involved in the process of situation development.

Scene No.	Scene Description

SCRIPT

EXPERT-ID: ______________________________ **Page** ___ **of** ___

SCRIPT: ______________________________

TRACK: ______________________________ SCENE: ______________________________

9a. *Considering that sequence of actions one at a time, let's take [scene description]. I'd like you to describe, in as much detail as possible, what would take place. Please begin by describing the purpose of this particular task.*

Subgoal:

M-M reference: (Ask "Why?" if not subgoal obviously approp.)

SCRIPT

EXPERT-ID: ______________________________ **Page** ____ **of** ____

SCRIPT: ______________________________

TRACK: ______________________________ SCENE: ______________________________

Action:	Frame(s)	M-M(s)
	frame-ids	*M-M id(s)*

FRAME

EXPERT-ID: ______________________________ Page ____ of ____

FRAME-ID: ______________________________ FRAME-STD SLOTS

(unique identifier)

Frame-of:

is-a:

a-kind-of:

similar-to:

has-parts:

part-of:

size: (range), (default

Description:

Spatial-Configuration:

FRAME

EXPERT-ID: ______________________________ **Page** ____ **of** ____

FRAME-ID: ______________________________ **ADDITIONAL SLOTS**

Slot/attribute name: attribute list

MENTAL MODEL

EXPERT-ID: ______________________________ Page ____ of ____

MENTAL-MODEL-ID: ______________________________
(unique identifier)

CONTEXT

1. *Why? (use that rule or procedure)*

Context:

MENTAL MODEL

EXPERT-ID: ______________________________ Page ____ of ____

MENTAL-MODEL-ID: ______________________________ OBJECTS

2. *Please list for me all the personnel, equipment, and any other things or people who are critical parts of this process. If they have their own set of objectives and ways of influencing the process, please describe that too.*

Object Description:	Goal:	Force:
(personnel, equipment, etc.)	*("objectives")*	*("influence")*

MENTAL MODEL

EXPERT-ID: ______________________________ Page ____ of ____

MENTAL-MODEL-ID: ______________________________ FORCES

3. *Now let's go over again all the sources of influence or power that will drive this process.*

Forces:

Frame(s):
frame-ids

MENTAL MODEL

EXPERT-ID: ______________________________ **Page** ____ **of** ____

MENTAL-MODEL-ID: ______________________________ **INTERACTION**

4. *Now, I'd like you to tell me how these different people and/or things that were identified earlier [refer to OBJECTS list] interact with one another in this process.*

Interactions:	M-M-ID	Frame(s)

MENTAL MODEL

EXPERT-ID: ____________________ Page ____ of ____

MENTAL-MODEL-ID: ____________________ RESULTS

5. *What are the various potential results of this process, based on these various, possible interactions? Please describe every plausible one you can think of.*

Result(s):	Frame(s):	M-M(s):

Analogy: Where Target is analogous to Reference

a. Reference Domain/System

b. Target Domain/System

c. Features of Similarity: (Complete list; when done, ask which of these features are most important to understanding the target domain/system. Put an asterisk (*) next to those features.)

d. Important Dissimilarities/Differences between reference and target domains:

Critical Incident Elicitation - "Good" Cases

a. Can you describe the features that would define an exceptionally good job at [developing the enemy Order of Battle]? What would define a really top-notch performance of this task?

b. So, if all I knew about the way an [OB] was done were those things you've listed, I could be confident of having a very good product?

c. Can you think of an actual case, in your experience, that would illustrate that kind of performance?

d. Can you think of other cases that similarly demonstrate a particularly skillful job of [developing an OB]?

Critical Incident Elicitation - "Bad" Cases

a. Can you describe the features that would define an exceptionally poor job at [developing the enemy Order of Battle]? What would define a really poorly executed performance of this task?

b. So, if all I knew about the way an [OB] was done were those things you've listed, I could reasonably expect that I would have a rather inferior product?

c. Can you think of an actual case, in your experience, that would illustrate that kind of performance?

d. Can you think of other cases that similarly demonstrate a particularly poor job of [developing an OB]?

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B.2 Generative Elicitation Forms for:

<u>Production Rules</u>:

- Identified
- Compartmentalized
- Generalized
- Chained

<u>Semantic Nets</u>:

- Frame - Standard Slots
- Frame - Additional Slots

<u>Mental Models</u>:

- Context
- Objects
- Forces
- Interactions
- Results

<u>Critical Incident Elicitation</u>:

- Good Cases
- Bad Cases

PRODUCTION RULES

EXPERT-ID: ______________________________ Page ____ of ____

PROBLEM (level of detail): ______________________________

____

____

______________________________ Production Rule:

Rule:	M-M(s): *(why?)*	Frame(s): *(what?)*

PRODUCTION RULES - compartmentalised

EXPERT-ID: ______________________________ **Page** ___ **of** ___

PROBLEM: ______________________________ **PRODUCTION RULES**

____

______________________________ **Compartment No.** sss

Antecedent Conditions: *(under which rules below apply)*

Consequent Rules:

Rule No:	Rule:	Frame(s)	M-M(s)

(e.g. rule no sss.ttt where sss = compartment no/ set of antecedent cond. and ttt = specific rule no. in that compartment)

PRODUCTION RULES - generalized

EXPERT-ID: ____________________ Page ____ of ____

PROBLEM: ____________________ PRODUCTION RULES

____

____________________ General Rule No. sss

Generalized Rule:

IF

THEN

Specific Instances of General Rule: *(fill this first then get general rule)*

Rule No.	Rule	Frame(s)	M-M(s)

e.g. rule no. xxx.yyy where xxx - genl rule no and yyy - specific rule no)

PRODUCTION RULES - chained

EXPERT-ID: ______________________________ Page ____ of ____

PROBLEM: ______________________________ PRODUCTION RULES

____

______________________________ CHAIN NO: ________

Ref: Preceding Rule #______ *(e.g., rule no. aaa.bbb where aaa = chain no. and bbb = rule no. in chain)*

Frame(s) M-M(s) (aaa)

_____IF

THEN

v

#

_____IF

THEN

v

#

_____IF

THEN

v

#

_____IF

THEN

v

#

_____IF

FRAME
(For Semantic Net)

EXPERT-ID: ______________________________ **Page** ____ **of** ____

FRAME-ID: ______________________________ **FRAME-STD SLOTS**
(unique identifier)

Frame-of:

a-kind-of:

similar-to:

size: (range), (default

Description:

Spatial-Configuration:

FRAME

(For Semantic Net)

EXPERT-ID: ______________________________ **Page** ____ **of** ____

FRAME-ID: ______________________________ **ADDITIONAL SLOTS**

Slot/attribute name: *attribute list*

MENTAL MODEL

EXPERT-ID: ______________________________ **Page** ____ **of** ____

MENTAL-MODEL-ID: ______________________________
(unique identifier)

CONTEXT

1. *Why? (use that rule or procedure)*

Context:

MENTAL MODEL

EXPERT-ID: ______________________________ Page ____ of ____

MENTAL-MODEL-ID: ______________________________ OBJECTS

2. *Please list for me all the personnel, equipment, and any other things or people who are critical parts of this process. If they have their own set of objectives and ways of influencing the process, please describe that too.*

<u>Object Description:</u>	<u>Goal:</u>	<u>Force:</u>
(personnel, equipment, etc.)	*("objectives")*	*("influence")*

MENTAL MODEL

EXPERT-ID: ______________________________ Page ____ of ____

MENTAL-MODEL-ID: ______________________________ FORCES

3. *Now let's go over again all the sources of influence or power that will drive this process.*

<u>Forces:</u> <u>Frame(s):</u>
frame-ids

MENTAL MODEL

EXPERT-ID: ______________________________ Page ____ of ____

MENTAL-MODEL-ID: ______________________________ INTERACTION

4. *Now, I'd like you to tell me how these different people and/or things that were identified earlier [refer to OBJECTS list] interact with one another in this process.*

Interactions:	M-M-ID	Frame(s)

MENTAL MODEL

EXPERT-ID: ______________________________ Page ____ of ____

MENTAL-MODEL-ID: ______________________________ RESULTS

5. *What are the various potential results of this process, based on these various, possible interactions? Please describe every plausible one you can think of.*

Result(s): Frame(s): M-M(s):

Critical Incident Elicitation - "Good" Cases

a. Can you describe the features that would define an exceptionally good job at [developing the enemy Order of Battle]? What would define a really top-notch performance of this task?

b. So, if all I knew about the way an [OB] was done were those things you've listed, I could be confident of having a very good product?

c. Can you think of an actual case, in your experience, that would illustrate that kind of performance?

d. Can you think of other cases that similarly demonstrate a particularly skillful job of [developing an OB]?

Critical Incident Elicitation - "Bad" Cases

a. Can you describe the features that would define an exceptionally poor job at [developing the enemy Order of Battle]? What would define a really poorly executed performance of this task?

b. So, if all I knew about the way an [OB] was done were those things you've listed, I could reasonably expect that I would have a rather inferior product?

c. Can you think of an actual case, in your experience, that would illustrate that kind of performance?

d. Can you think of other cases that similarly demonstrate a particularly poor job of [developing an OB]?

B.3 Generative Elicitation Using a Specific Problem

The generative approach to elicitation involved the messages contained in the "PERINTREP Number 14" and the "INTSUM Number 21" presented in Appendix C. In contrast to the use of those materials in interpretative elicitation, the generative method involved giving those messages to the subject one at a time, without supplying the background information and order of battle templates from Appendix C. When messages made reference to map coordinates, the subject was given blank maps (USACGSC 50-323 and USACGSC 50-324) on which to plot information.

APPENDIX C

PROBLEM SOLVING SCENARIO

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BACKGROUND

You are a replacement G2 operations officer or OB analyst recently assigned to the 54th Infantry Division. You have been provided some basic information on the enemy order of battle and the general tactical situation.

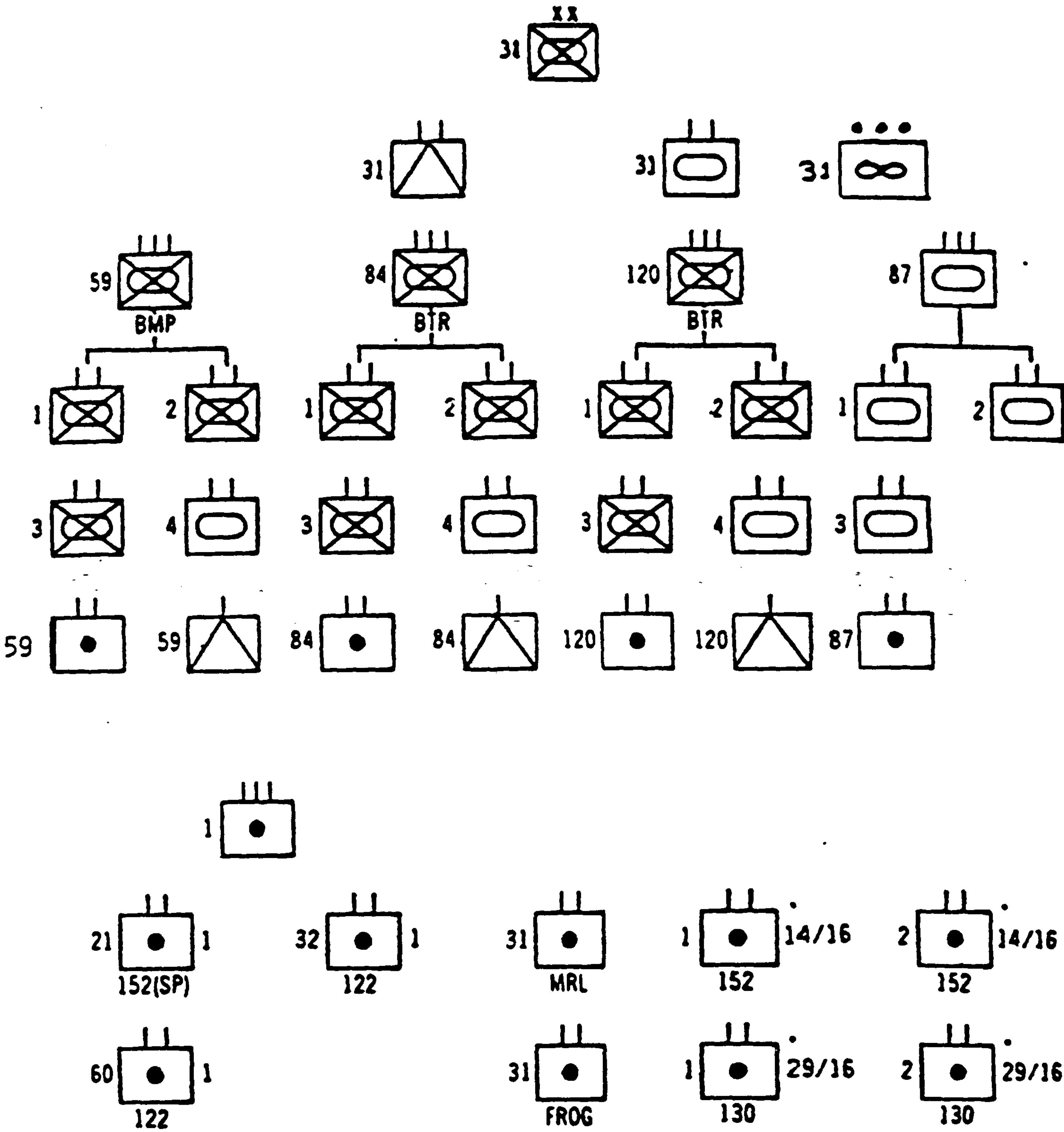
CURRENT SITUATION

The U.S. 10th Corps has ordered the 54th Infantry Division, currently in reserve, to conduct an attack through the 23rd Armored Division to seize the high ground in the vicinity of Neukirchen (OBJ 1). Based on the terrain, there are two avenues of approach that the division might use. Elements of the 31 GMRD and 49 MRD are defending astride these avenues.

The enemy forces opposing the 23rd Armored Division are in defensive positions and essentially deployed as depicted on the overlay.

SPECIAL SITUATION/TASK

As the new G2 operations officer/OB analyst, you would by now have some familiarity with the enemy situation and are now prepared to take appropriate actions in response to reported changes in the enemy situations as the information is provided from reports and intelligence summaries. Key to this exercise is that the interviewer will want to know what, if anything, each new piece of information means to you, as G2 operations officer/OB analyst, and what actions you would take.



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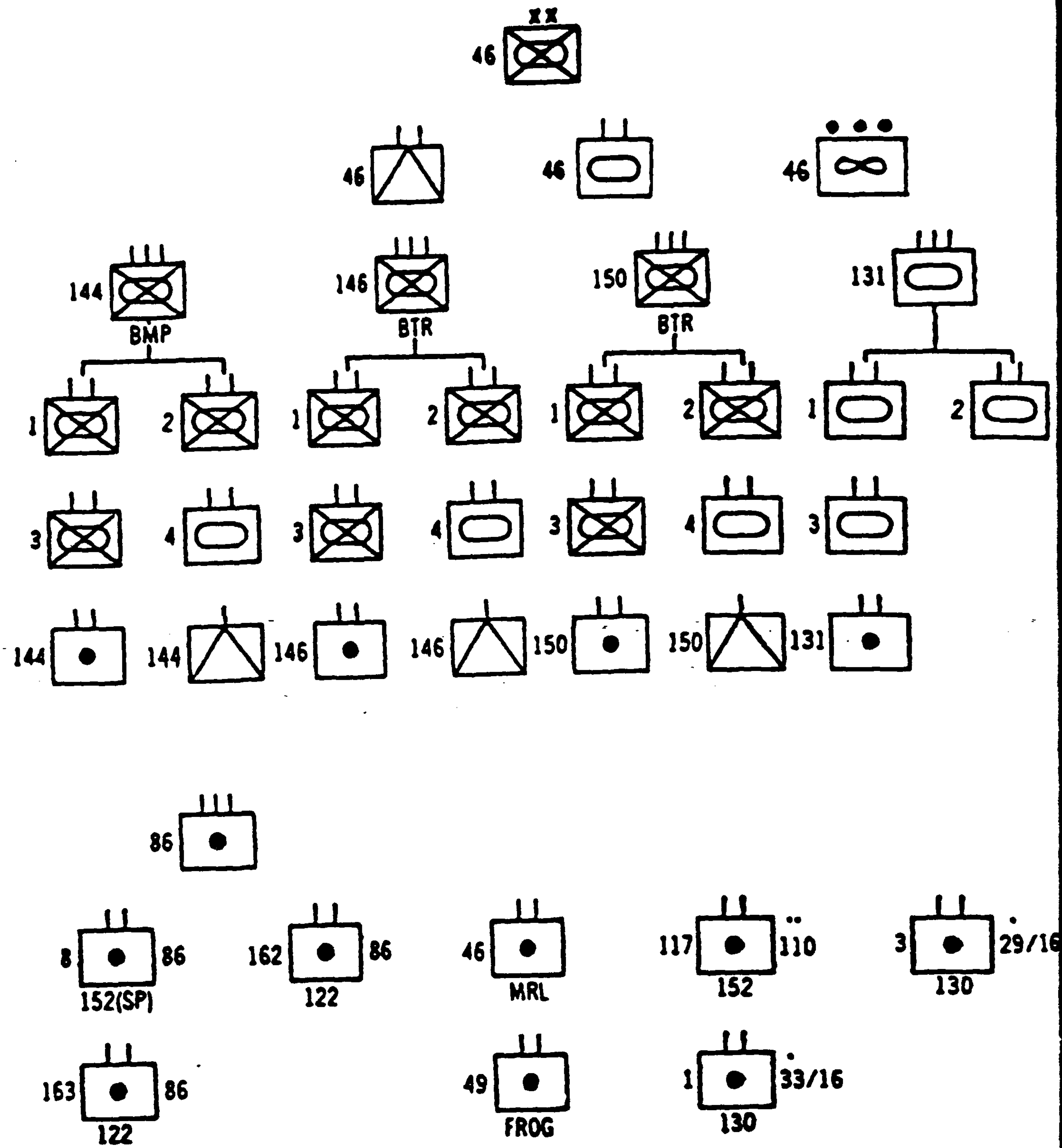

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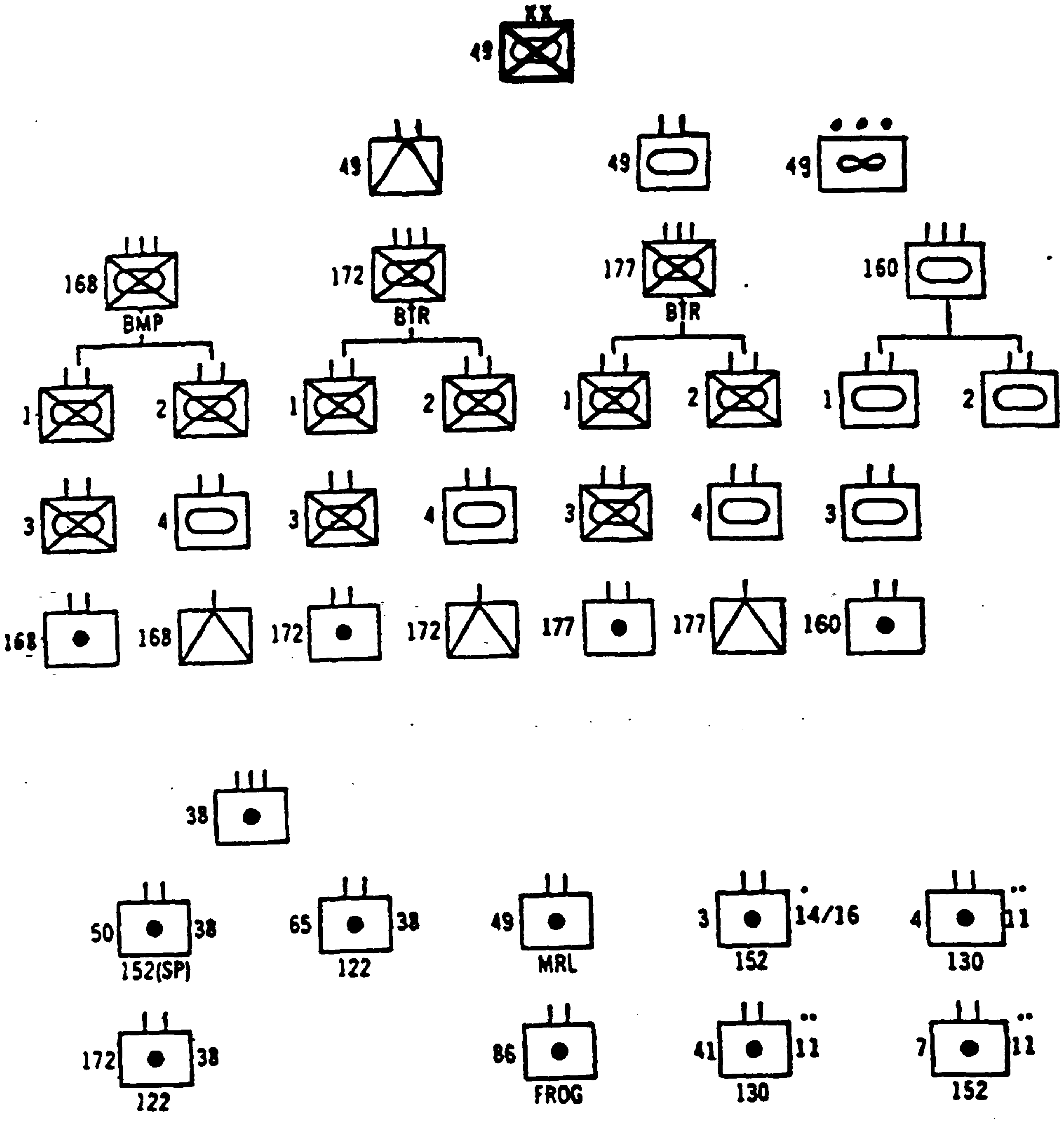
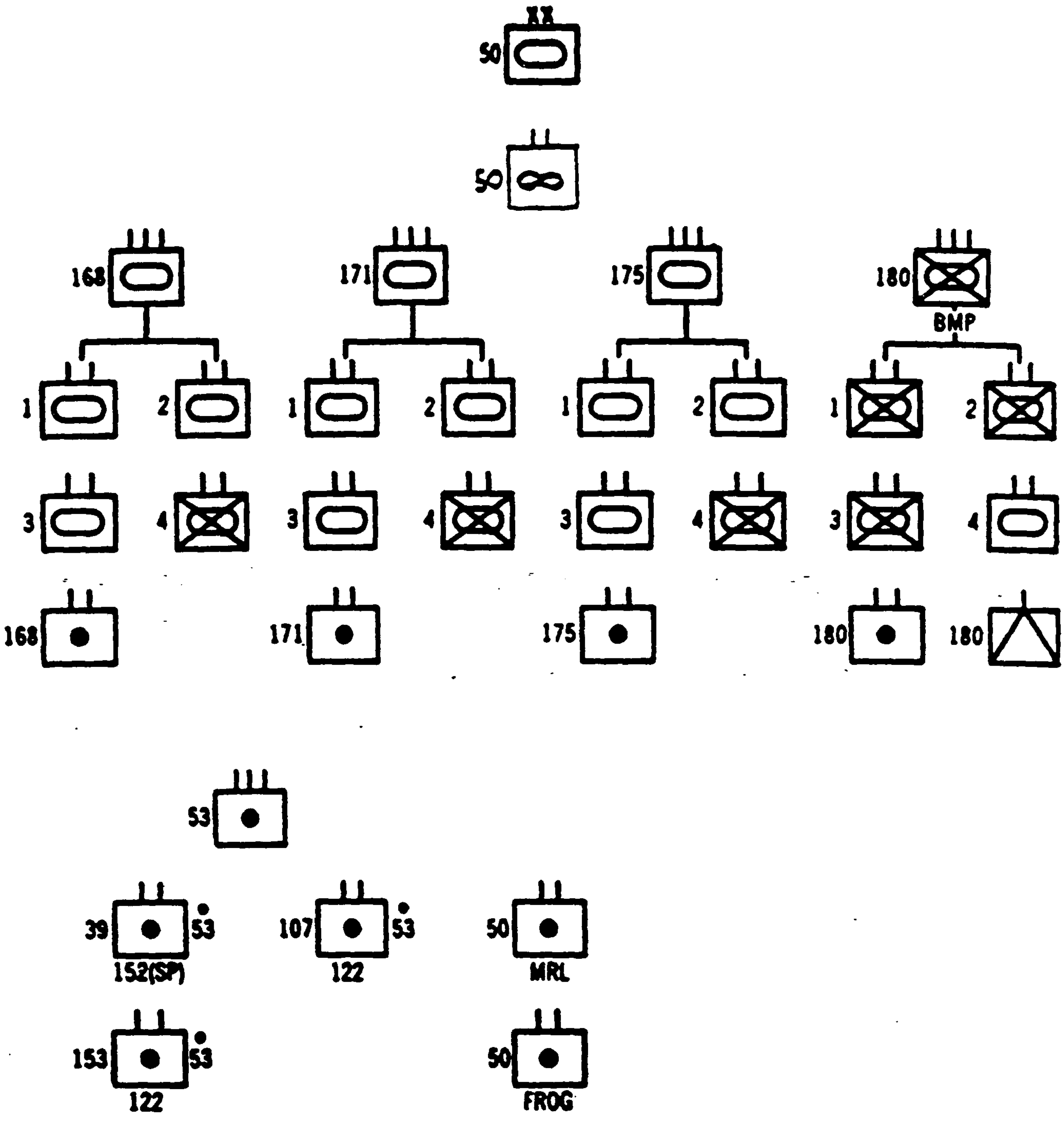
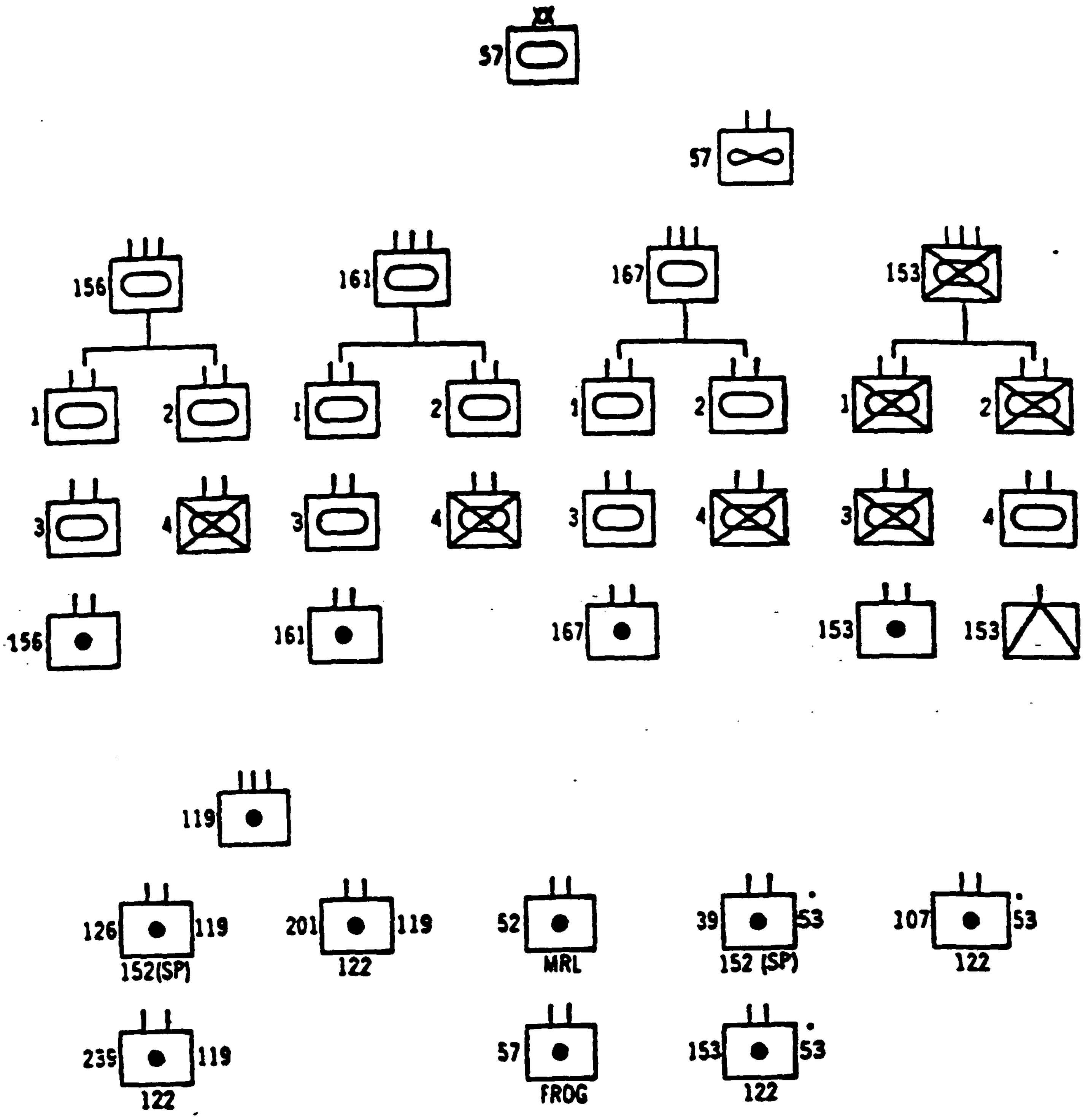
** ATTACHED FROM CAA



* ATTACHED FROM FRONT
** ATTACHED FROM CAA



•ATTACHED TO 57 TKD



* ATTACHED FROM 50 TKD

Copy no ____ of ____ copies
10th (US) Corps
________________ GERMANY
302130 August ____

PERINTREP NO 14

Period Covered: 280500 to 290500 August

References: Map, series USACGSC 250-156, Germany, sheet 1 (MUNSTER--WURZBURG), edition 1982, 1:250,000 (Map B (sheet 1 of 2)).

Map, series USACGSC 250-157, Germany, sheet 1 (MAGDEBURG--LEIPZIG), edition 1982, 1:250,000 (Map B (sheet 2 of 2)).

1. GENERAL THREAT SITUATION

Threat 24 CAA defends from MARBURG (MB8428) to GRUNBERG (MB9704) to FELDKRUCKEN (NB1300) to DIRCHBRACHT (NA2084) to ROMSTHAL (NA2774) to MARJOB (NA3768) with the 31 GMRD, 49 MRD, 57 TD, and the 46 MRD north to south. The 50 TD has been confirmed as occupying the second defense belt in the 24 CAA sector.

2. THREAT ACTIVITIES

a. Ground.

(1) Dissatisfaction evident in 57 TD because unit has been given last priority on supplies, including artillery ammunition and rations. 31 GMRD has first priority.

(2) Airphoto reconnaissance confirms that main defense belt will be located in immediate vicinity of current line of contact. No security zone will be formed, but local security has been placed forward.

(3) Movement forward of additional forces to support the Southern Front is being hampered by Allied air interdiction and the overall lack of success of attack in southern zone.

(4) 50 TD (second defense belt) has been ordered to radio-listening silence effective 282100 August.

(5) Intercept recorded 280700 August restricted first-echelon MRD artillery units from firing counterbattery fire "unless threat forces' fire is producing major losses of personnel and equipment."

(6) Above-normal level of threat administrative/logistics transmissions were noted throughout the reporting period.

(7) Movement of engineer units and building materials forward along threat main supply routes (MSRs) appears to have increased.

(8) Following input from HUMINT, IMINT, and SIGINT has been received during this period.

(a) STRAIGHT FLUSH radar identified at coordinates NB388146 at 290331 Aug.

(b) FAN SONG radar identified and located NB454131 at 290300 Aug.

(c) PAT HAND radar identified at coordinates NB585175 at 280600 Aug.

(d) PAT HAND radar identified and located at NB689191 at 290115 Aug; previously identified only as SAM battalion.

(e) FAN SONG radar identified and located NB610240 at 290513 Aug.

(f) STRAIGHT FLUSH radar located at coordinates NB440290 at 270421 Aug.

(g) LONG TRACK radar located NB475295 at 282213 Aug.

(h) PAT HAND radar identified and located at coordinates NB520313 at 290141 Aug.

(i) Communications from UI SCUD unit NB545350 to 24 CAA observed 281935 Sep. Unable to monitor 24 CAA communications.

(j) FAN SONG radar identified and located at NB610350 at 290245 Aug; previously thought to be located NB6335.

(k) LONG TRACK radar located NB372442 at 290017 Aug.

(l) LONG TRACK radar located NB421400 at 290043 Aug.

(m) LONG TRACK and PAT HAND radars collocated at NB481432 at 290051 Aug.

(n) LONG TRACK radar confirmed coordinates NB581475 at 290357 Aug; previously thought to be located NB5548.

(o) UI SCUD unit at NB666435 observed communicating with front at 281943 Aug. Front communications not observed.

(p) UI SCUD bn at NB5444 detected by IMINT at 281530 Aug.

(q) UI engineer unit with two tactical float (PMP) bridges in place at NB4327 at 281530 Aug detected by IMINT.

(r) UI engineer unit at NB4731 with two tactical float bridges (PMP) at 281530 Aug detected by IMINT.

(s) UI engineer unit assembly area located by IMINT vic NB4215 at 281530 Aug.

(t) CAA chemical defense unit located by IMINT vic NB7130 at 281530 Aug.

(u) SCALEBOARD bn located by IMINT vic NB7447 at 281540 Aug.

(v) SCALEBOARD bn located by IMINT vic NB7433 at 281545 Aug.

(w) UI airborne unit assembly area, possible regiment size, located vic NB9149 by IMINT at 281545 Aug.

(x) Class I, III, and V support area located by IMINT vic NB6937 at 281545 Aug.

(y) Class V support area located by IMINT vic NB4804 at 281545 Aug.

(z) UI engr bn assembly area vic NB9434 located by IMINT at 281550 Aug.

(aa) UI MRD in assembly area vic GERA (QB1740) confirmed by IMINT at 281600 Aug.

(bb) Class I, III, and V support area confirmed by IMINT at PB2045 at 281555 Aug.

(cc) Class V support area confirmed by IMINT at PB4352.

(9) The following battalion-sized units are believed to have been rendered combat-ineffective and assimilated into adjacent units as replacements:

31 GMRD
- 3 GMRB, 59 GMRR
- 1 GMRB, 120 GMRR
- 3 GMRB, 120 GMRR
- 4 GTB, 120 GMRR
- 3 GTB, 87 GTR
- 32 (122-mm) Gds Arty Bn, 1 Gds Arty Regt
- 120 (122-mm, SP) Gds Arty Bn, 120 GMRR
- 87 (122-mm, SP) Gds Arty Bn, 87 GMRR

57 TD
- 3 TB, 167 TR
- 3 MRB, 153 MRR

49 MRD
- 3 MRB, 168 MRR
- 3 MRB, 172 MRR
- 3 MRB, 177 MRR
- 3 TB, 160 TR
- 65 (122-mm) Arty Bn, 38 Arty Regt

46 MRD
- 3 MRB, 144 MRR
- 3 MRB, 146 MRR
- 4 TB, 146 MRR
- 3 MRB, 150 MRR
- 162 (122-mm) Arty Bn, 86 Arty Regt

b. Air. Threat air during the reporting period has been active. The preponderance of available air sorties has been used to establish air superiority over the 10th (US) Corps sector but, at best, threat air has been able to achieve only air parity. Although the 24 CAA is not the main effort of the *front*, it is expected that air support from the *front* air division will continue. It is anticipated that the 24 CAA will receive approximately *four* sorties per hour. The helicopter detachment or squadron at division level will continue to provide limited administrative (liaison) support. Attack helicopters in the helicopter squadron will most likely be employed with the division counterattack force.

c. Electronic Warfare.

(1) Strict SIGSEC measures have been imposed on all 50 TD units.

(2) Barrage jamming was experienced on frequencies in the FM bands periodically throughout the reporting period.

d. Other. An FM transmitter tentatively located at NB029200 reported reaching a destination and requested further instructions. No response was monitored and, after several attempts to establish communications, the transmissions ceased.

3. ANALYSIS AND DISCUSSION

a. The 24 CAA currently is defending approximately 75 to 80 kilometers of frontage. Although this frontage is not excessive for a CAA at or near full strength, the 24 CAA is overall at approximately 70-percent strength in personnel and equipment.

b. The threat holds hastily prepared positions along the current line of contact. Although continuing to improve its defenses, a severe lack of engineer assets continues to plague its effort.

c. The 57 TD positions are receiving only light attention. More emphasis appears to be going to the main defense belt positions on the REISKIREHEN--ALSFELD corridor and the STEINAU--FULDA corridor.

d. Threat is capable of delaying from current positions eastward.

4. CONCLUSIONS

The 24 CAA will attempt to defend along the current line of contact awaiting the outcome of the major threat effort in the north. The 24 CAA remains vulnerable to a continued corps offensive.

* * * * * * *

PART FIVE. EXTRACT, 23D ARMD DIV INTELLIGENCE SUMMARY (INTSUM) NO 21

SECRET For Training, Otherwise Unclassified

IMMEDIATE

FROM: CDR, 23D ARMD DIV

TO: CDR, 10TH (US) CORPS

INFO: CDR, 3D (GE) Corps
CDR, 54TH MECH DIV
CDR, 53D MECH DIV

* * * * * * *

INTSUM NUMBER 21, ENDING 302400 AUG ____.

THREE ALFA.

(1) AT 1830 A COMPANY-SIZED FORCE, REINFORCED WITH TANKS, CONDUCTED A LIMITED OBJECTIVE ATTACK FROM THE NORTHEAST ON THE LEIDENHOFER KOPF (MB8617). UNSUCCESSFUL, THE THREAT FORCES WITHDREW TO HASTY DEFENSES VICINITY MB878180 AND MB888168.

(2) COMBAT PATROLS ENGAGED PLATOON-SIZED THREAT POSITIONS VICINITY MB857238 AND MB861223. AT LEAST ONE TANK WAS DUG-IN IN THE POSITION AT MB857238.

(3) 12 TANKS REPORTED IN ONE ASSEMBLY AREA VIC WITTELSBERG (MB9023).

(4) A COMBAT PATROL ENGAGED A THREAT PLATOON IN A HASTY DEFENSIVE POSITION VICINITY OF MB885159. THE POSITION DID NOT APPEAR TO HAVE OVERHEAD COVER AND THE COMMUNICATIONS TRENCHES WERE NOT YET COMPLETED. THE PATROL REPORTED THAT WHEN FIRST SIGHTED, THE THREAT APPEARED TO BE EMPLACING MINES BY HAND.

(5) UNITS HAVE REPORTED RECEIVING TANK AND ATGM FIRES FROM THE VILLAGE OF RABENAU (MB9113), AND FROM AT LEAST A COMPANY-SIZE FORCE IN POSITIONS IN VICINITY OF MB920122, MB937123, AND MB938114.

(6) REFUGEE REPORTS:

(A) FORCED TO DIG TRENCHES AND BUNKERS IN A WOODLINE 1 KM EAST OF KESSELBACH (MB9113).

(B) FORCED TO DIG 10 EMPLACEMENTS FOR ANTITANK GUNS, PROBABLY 100-MM, IN A WOODLINE OVERLOOKING THE MAIN HIGHWAY 2½ KM SOUTHWEST OF ERMENROD (NB0911).

SECRET For Training, Otherwise Unclassified

ITSUM 21

(C) FORCED TO DIG HULL-DOWN POSITIONS FOR WHEELED ARMORED VEHICLES (PROBABLY SAGGER BRDM) IN THE WOODLINE ON THE SOUTHERN SLOPE OF THE TUMMELBERG (MB9811).

(D) CONFIRMED A COMPANY-SIZED CP LOCATED ON THE HEGBERG (MB9709). BELIEVED TO BE THE 1ST CO, 1 MRB, 168 MRR, 49 MRD.

THREE ECHO. THE LIMITED OBJECTIVE ATTACK ON THE LEIDENHOFER KOPF WAS PRECEDED BY ONLY A SHORT 10-MINUTE ARTILLERY BARRAGE.

FOUR ALFA. DURING THE PERIOD, AN ESTIMATED 15 KIA WERE REPORTED.

FOUR BRAVO.

(1) THREE WOUNDED PRISONERS WERE CAPTURED AT THE LEIDENHOFER KOPF. THEY INDICATED THAT THEIR PLATOON WAS ORDERED TO DEFEND LONDORF (MB9013). DOCUMENTS FOUND ON ONE OF THE PRISONERS INDICATED THAT HE WAS FROM THE 2 CO, 2 GMRB, 59 GMRR, 31 GMRD.

SEVEN ALFA. REFUGEE REPORTS:

(1) A REGIMENTAL-SIZED CP (BELIEVED TO BE THE 172 MRR, 49 MRD) LOCATED IN RUPPERTENROD (NB0608). ALSO THE 1 MRB CP IS COLLOCATED WITH THE REGIMENTAL CP.

(2) A PREVIOUSLY UNDETECTED 152-MM GUN/HOW BATTALION (2/14/16?) LOCATED VICINITY OF HOINGEN (MB9418).

(3) RECONNAISSANCE ELEMENTS OF THE 175 TR WERE REPORTED IN KIRTORF (NB0824).

(4) THE 86 FROG BATTALION (49 MRD) LOCATED NB1018.

(5) THE 87 GTR (31 GMRD) LOCATED IN NEIDERKLEIN (MB9927).

(6) TANKS, IDENTIFIED BY BUMPER MARKINGS, OF THE 168 GTR, 50 TD, WERE REPORTED IN EICHENAU (NB3707).

EIGHT AND NINE.

(1) AT 1930 A COLUMN OF 25 TANKS WAS DETECTED MOVING SOUTH ALONG THE MAIN ROUTE TOWARD MARDORF (MB9423).

(2) AT 1935 A COLUMN OF 20 TANKS WAS DETECTED MOVING WEST ALONG THE AUTOBAHN (E4) TOWARD EHRINGSHAUSEN (NB0717).

ITSUM 21

TWELVE.

(1) THE LOCAL ATTACK AT 1830 APPEARS TO HAVE BEEN AN ATTEMPT BY THE THREAT TO IMPROVE HIS DEFENSIVE POSITION BY DENYING US OBSERVATION AND FIRES FROM THE LEIDENHOFER KOPF. THE SHORT (10-MINUTE) BARRAGE INDICATES THAT THE THREAT MAY BE EXPERIENCING A SHORTAGE OF ARTILLERY AMMUNITION.

(2) WITH THE EXCEPTION OF LOCAL ATTACKS AIMED AT IMPROVING DEFENSIVE POSTURE, IT APPEARS THAT THE THREAT INTENDS TO CONTINUE THE DEFENSE IN ITS CURRENT POSITIONS.

* * * * * * *

OTHER ENEMY ACTIVITY

1. NEW UNIT SIGHTING

A POW from 2nd Battalion, 84 MRR said that he had seen T-80 tanks in an assembly area near MARDORF (NB 9424). He heard that a Guards Tank Division would attack in the 31st MRD area. The 31st MRD has T-64 tanks.

NOTE: Thus information conflicts with all other reports and estimates and poses a good opportunity to test interviewee's production rules.

2. EMPLOYMENT OF NUCLEAR WEAPONS

An IMINT report tentatively identifies a convoy of 6 transporters carrying SCUD missiles at (NB 4030). This is the first sighting of a possible SCUD battalion resupply.

NOTE: Since nuclear weapons have not been used up to this point, this report raises the question of a possible nuclear or chemical attack. Also, this sighting is forward of any known SCUD battalion location.

3. EMPLOYMENT OF CHEMICAL MUNITIONS

10th Corps reports that a POW from the 84th MRR said his company was instructed to wear chemical protection coveralls at all times. A second report identified covered ammunition trucks with unusually heavy security delivering munitions to artillery units in 31st MRD. Some drivers were wearing protective suits.

NOTE: This is a first report on possible use of chemical weapons and does not fit previous pattern of intelligence reports.

APPENDIX D

INTERPRETATIVE AND GENERATIVE ELICITATION DATABASES FOR SITUATION DEVELOPMENT AND ORDER OF BATTLE

APPENDIX D

CONTENTS

I. SITUATION DEVELOPMENT KNOWLEDGE BASE CONSTRUCTS

A. Situation Development: Interpretative Elicitation Methods

1. Scripts

Script: Situation Development

Tracks: Echelon
- Battalion - pointer to BN subscript
- Division

Conflict:
- Low-intensity - pointer to low-intensity frame
  - Features: less technical in low-intensity conflict
- High-intensity - pointer to high-intensity frame
  - Features: more time sensitivity, higher lethality, more firepower that can be used quickly

D-Main: Pointer to D-Main frame
D-Tac: Pointer to D-Tac frame

Goals:
- Determine enemy's intent
- Preempt enemy's plan and operation
- Cause initiative to move to U.S. Commander
- Stop enemy from impacting on friendly forces
  - Subgoal: Kill enemy
  - Subgoal: Target enemy
- Obtain knowledge of current and future situations by echelon: battalion, brigade, division
- Let commander know what enemy is doing

At D-Main:
- Plan the next battle 24, 28, 72 hours out
- Provide commander and G-3 with what they need for their mission: knowledge of enemy, terrain, and weather

At D-Tac:
- Knowledge of current battle less than 24 hours out
- Knowledge of battlefield within 10 km of FEBA

Entry
Conditions: Ongoing
Changes in process driven by
Start of war
Findings as a result of analysis
Enemy actions

Roles: Intelligence analyst - pointer to analyst frame
Support element
G-1
G-4

At D-Main: Commander
G-2
G-2 operations/situation developer
Assistant G-3
Terrain personnel
Staff weather officer
Electronic warfare officer
Collection manager
Collection management on
dissemination staff
Operations security

At D-Tac: G-3
Assistant division commander -
Operations and Training

Props: Maps
Situation map
Templates
Order of battle sheets
Gazeteer/reference book
Workbooks
Imagery products (photos, infrared, radar)
Information reports (from reconnaissance
systems, interrogations, SITREP from forward
units)
Analysis of area of operations
FM radios
G-2 hot loop
Multi-channel phone systems
Command vehicle

Results: May get conflicting information
May get information with no identifiable
bearing on current situation - pointer to
intelligence analyst frame
May get information that does not support
previous conclusion

Products: Estimate of situation (written in
All-Source Production section of D-Main)
Intelligence preparation of the
battlefield (IPB)

INTSUM (Intelligence Summary)
PERINTREP (Periodic Intelligence Report) - done every 6 to 12 hours

At D-Main: Intelligence reports sent to D-Tac
Spot reports sent to D-Tac
Briefings
Intelligence annex (enemy situation or forecast)

At D-Tac: No formal reports
Spot or intelligence reports as information comes in
Good result: locate units and what they are doing

Scenes: *(Note: Since these are combined from more than one expert, the ordering may not correspond exactly to how they would be performed.)*

1) Get briefed as you come on shift

Actions: Briefed on analysis of area of operations, weather, terrain, and enemy situation
Read current plan
Read current order of battle
Read current situation estimate
Briefed on commander's and higher commander's intent
Understand what own unit is doing in terms of attack and defense
Assess enemy historical and current actions in terms of doctrine and departure from doctrine
See what chemicals have been used

2) Look at terrain

Actions: Look at avenues of approach through area of mission
Call terrain analysts

a) Find out status of bridges and roads along avenues of approach
b) Find out where choke points are and where enemy can stop us
c) Get assessment of enemy morale
d) See if there are indications of logistics and resupply problems

3) Call staff weather officer

Actions: Get forecast for next 3 days. Make sure information gets to ASPS

4) Talk to personnel of division that is on-line defending (if any)
Talk to G-2 operations

Actions: a) Get assessment of what enemy units in
b) What is first defensive belt doing and how they are doing it
c) Get assessment of enemy morale
d) See if there are indications of logistics and resupply problems

Talk to G-2:
a) See what threats and resistance friendly battalions and brigades will face as they pass through axes of advance into enemy territory

5) Talk to personnel of on-line brigade holding key avenue of approach

Actions: Talk to S-2
Talk to commander
Get assessment of what enemy units in first defensive belt are doing and how they are doing it
Get assessment of enemy morale
See if there are indications of logistics and resupply problems

6) Generate questions that need to be addressed for mission

Actions: Get intelligence requirements from commander (D-MAIN)
G1, G3, G4 generate questions as part of their plans

7) Go to all source production section

Actions: Tell them what information is needed

8) Go to collection management and dissemination section

Actions: Tell collection manager what information is needed to ensure that their information gets to ASPS

9) Interaction with counterparts at higher and adjacent units

Actions: Contact by radio or liaison officers
Share assets
Exchange information
a) Understand how they manage collection assets so they can maximize their use

10) Conduct limited reconnaissance

11) Analysis of incoming information

Actions: Look at 2d echelon forces
Look at flank situation
Look at artillery groupings, regimental, and divisional
If using air, look for air defense artillery assets
Look at current enemy forces
Look at chemical assets
Look at what all divisions are doing

Look at electronic warfare assets
Look at engineering assets
a) If brigade is forward then planning attack

12) Evaluate

Actions: Compare situation to enemy doctrine
Compare situation to enemy recent pattern of operations
Have we looked deep enough?
Determine how commander's mission can be supported
Assess enemy strength

13) Brief commander

Track: D-Tac

Scenes:
1) Raw information comes in
2) Post information relevant to current battle on map
3) Pass information to D-Main
   Actions: Decide what information is important to them
4) Log information in journal
5) Get information from commander and G-3 on what to look for
   a) May include obstacles, key bridges, enemy forces, sympathy of population

Track: Battalion intelligence gathering

Goals:
Determine force in contact
Determine enemy's disposition
Determine enemy's morale
Determine enemy's intent
Take advantage of known weakness in C^2 or C^3

Entry Conditions: Battalion comes in contact with enemy

Roles: S2, prisoners (squad leaders, company commanders)

Scenes: 1) Take prisoners

Actions: a) Use intelligence to go after higher person and command post at battalion, regiment, and higher

Script: Collection Management and Dissemination

Goals: Collect and disseminate information about enemy

Roles: Collection manager, ASPS, commander, G-2, G-2 operations

Props: Radars, radios, photo

Results: Get data on enemy

Scenes: 1) Identification of intelligence requirements

Actions: G-2 operations or G-2 or ASPS state what information is needed

2) Generation of collection plan

Actions: Collection manager generates plan for collecting data

3) Task units

Actions: Collection manager tasks units to collect data
a) If right collection assests do not belong to collection manager, then s/he asks next higher unit for data

4) Information comes in

Actions: Receive information from AV reports, Corps reports, national reports

5) Dissemination

Actions: When data comes in give to ASPS
When reports come in, disseminate throughout unit

Script: All Source Production Section (ASPS)

Goals: Analyze intelligence data

Roles: OB tech, OB analyst, analysts, G-2, G-2 operations, chief of ASPS, commander, collection manager

Results: Write estimate of situation

Scenes: 1) Identification of intelligence needs

Actions: G-2 or G-2 operations tells ASPS what information is needed

2) Interact with CMDS

Actions: Tell them what gaps are in intelligence

3) Interact with terrain analysts

Actions: Tell them what gaps are in intelligence regarding terrain

4) Analyze data

Actions: Get electronic, signal, photo intelligence synthesis into coherent intelligence product

5) Write estimate of situation

Script: Pre-battle Situation Development

Goals: Develop contingency plans

Subgoal: Keep plans up-to-date

Entry Conditions: World events
Political decisions
New month

Roles: Joint chiefs of staff
Politicians

Props: Plans existing

Outcomes: Updated plans

Scenes:
1) Review plans
2) Look at political and world events
3) Make inferences regarding potential mission of unit
4) Update or generate plans

2. Frames

Frame: D-Main

Has parts: ASPS, collection management and dissemination section, terrain detachment, staff weather officer, collection assets, finished intelligence

Mission: Plan operations 24, 48, 72 hours out
Plan next battle

Personnel: G-2, deputy G-3, collection manager, commander

Frame: D-Tac

Has parts: Raw information

Mission: Run current battle
Look less than 24 hours out (default 8 to 12 hours)
Look within 10 km of FEBA

Personnel: G-3, assistant division commander for operations and training

Spatial Configuration: Located near FEBA with brigades

Frame: Collection Management and Dissemination Section

Is a: Intelligence unit

A-kind-of: Divisional asset

Has-parts: Patrols; communications, electronic and surveillance systems, ground surveillance radars; airborne and ground based platforms; imagery reconnaissance (photo, infrared, radar)

Part-of: Division intelligence element

Personnel: Collection manager

Mission: Provide intelligence information to analysts

Frame: Soviet Offense

Is-a: Battle formation

Has-parts: Divisions, regiments, artillery, electronic warfare assets, engineer assets, logistics, nuclear, biological, and chemical (has-mission, seal flanks) weapons

Activity: Movement of units forward
Firing active

Spatial Configuration: Two units up, two back
Division frontage 8 to 16 km
Artillery forward--2/3 range past FEBA
Electronic warfare assets on flanks
Engineer assets forward

2nd echelon regiments spaced 2 to 3
hours between them
Regimental assets at rear of formation

Attributes: Combat units strong

Frame: Friendly Offense

Is-a: Battle formation

Has-parts: Divisions, terrain, avenues of approach, objectives, air and ground forces, enemy units

Spatial Configuration: Divisions are within boundaries
Avenues of approach run through division boundaries
Objectives (has-part terrain) are phased
Enemy on other side of FEBA - pointer to enemy defense frame

Frame: Soviet Prepared Defense

Frame of: Defensive operation

Is-a: Battle formation

Has-parts: Combat units, headquarters, telephone wires, radios, artillery, overhead cover, communication trenches, mine fields, engineer units
has-part: building materials

Activities: Enemy digging in
Lots of artillery used
No forward movement

Spatial Configuration: Layers: Screen of platoons forward
First defense belt
a) Supporting elements to rear and adjacent
Second belt
Third belt
Antitank or counterattack force in 2nd or 3rd belt
Reinforcements behind 2nd belt

Attributes: Combat units weak

Frame: Hasty Defense

Frame of: Defensive operation

Is-a: Battle formation

Has-parts: Air defense (mission: protect command posts, logistics sites, bridges), artillery, command posts, logistics sites, bridges

Mission: Hold off enemy attack until own 2d echelon attack can be reformed

Spatial Configuration: Division frontage 15 to 25 km
Artillery forward--2/3 range past FEBA
Air defense assets near command posts, logistics sites, bridges

Frame: Chemical Warfare

Frame of: Fighting strategy

Is-a: Warfare

Has-parts: Friendly and enemy units, chemicals

Results: Impedes battle conditions

Initiated by: Friendly stronger than enemy

Frame: High Intensity Conflict

Frame of: Battle

Is-a: Conflict

Description: Europe
Mechanized and armored warfare
Large numbers of forces involved
Full range of weapons

Spatial Configuration: Battlefield characterized by width and depth
No halts or breaks in battlefield

Attributes: Weapons--accurate, lethal

Contrasts with: Low-intensity conflict

Comparative Features: Weapons less technical in low-intensity conflict
Support procedures less correlated in low-intensity conflict
Analytical effort constant in both
More firepower in high-intensity conflict

More destruction brought quickly in high-intensity conflict
High-intensity more dynamic
Know what enemy will do early and with what and where in high-intensity conflict

Frame: Low Intensity Conflict

Frame-of: Battle

Is-a: Conflict

Has-parts: Weapons, support procedures

Opponent: Third world military force

Features: Weapons--not sophisticated
Support procedures--not sophisticated

Contrasts with: High-intensity conflict

Comparative Features: Weapons more technical in high-intensity conflict
Support procedures more correlated in high-intensity conflict
Analytical effort constant throughout both

Person Frame: G-2 Operations

Tasks: Supervises intelligence gathering and production

Knowledge: Not necessarily expert on enemy
Knows where to get information
a) Knows capability of information gathering systems

Person Frame: Good Intelligence Analyst

Knowledge: Knows enemy tactics, capabilities, and limitations

Capabilities: Can avoid self deception
Keeps an open mind

3. Mental Models

Mental Model: Surprise Attack

Context: Battlefield

Goals: Seize objectives before enemy can respond
Cause disarray in enemy

Objects: Friendly units
Enemy units
has-part: supporting
has-part: first echelon

Forces: Combat forces
Mobility

Force/Object
Interactions: Friendly force impacts enemy force
Friendly force uses intelligence to target obstacles to movement
Friendly force destroys obstacles--pointer to M-M destroy

Outcomes: Friendly forces advance impeded
Enemy cannot react quickly
Friendly forces achieve objectives

Mental Model: Cooperation

Context: General

Current
Instantiation: Exchange of corps and division intelligence information on battlefield

Goals: Assist commander's mission and conceptions
(missions have property compatible)

Objects: Information
Corps and division collection assets
Analysts

Forces: Common goals
Common understanding

Force/Object
Interactions: Division commands has mission
Corps commander has mission
Division commander and staff have information relevant to corps commander's mission
Corps commander and staff have information relevant to division commander's mission

Division commander and staff understand division commander's mission
Corps commander and staff understand division commander's mission
Division commander and staff give information to corps commander and staff and ask them for information
Corps commander and staff give information to division commander and staff

Outcomes: Corps and division commanders and staff have information they need
Corps and division commanders and staff have broader assessment and understanding of situation
Corps and division commanders can better achieve their missions
Relationships between corps and division commanders and staffs have been improved

Mental Model: Self Deception About Enemy

Context: Battlefield (universal)

Goal: Understand enemy

Objects: Intelligence analyst
Information
Enemy forces
is-a: Soviet
or is-a: Third World Force

Force: Reasoning process

Force/Object
Interactions: Reason that third world country have primitive capabilities
Reason that Soviet forces are overly strong

Outcomes: Develop misconcept which result in loss of life on battlefield

Mental Model: Disrupt Enemy Forces

Context: Battlefield (universal)

Goal: Kill enemy before he can take action that would impact on friendly forces

Objects: Enemy forces
(Friendly forces)
Enemy commander
Friendly commander
Friendly intelligence officer

Forces: Combat power
(Reasoning power)

Force/Object
Interactions: Friendly forces strike before enemy forces contact

Outcomes: Enemy plan disrupted
Enemy train of thought disrupted
Enemy intention disrupted
Enemy force destroyed
Enemy forces do not impact on friendly forces
Initiative goes to friendly commander

B. <u>Situation Development: Generative Elicitation Methods</u>

1. <u>Production Rules</u>:

<u>a. Tactics/Doctrine</u>

If enemy is in hasty defense,
then they will be going into attack mode or they will wait for reinforcements and they will not be very long

If enemy attack is reinforced with tanks,
then objective of the attack is important or the attack is a supporting one and more force is needed to defeat its enemy

If enemy has insufficient organic force to conduct successful attack,
then it will attach other forces to the fighting force

If the commander is a brigade level,
then he needs to know about company size forces

If commander or intelligence analyst is at an echelon,
then he needs to know about composition of units that he is fighting and composition of flanking units and composition of rear units

If commander or intelligence analyst is at brigade,
then s/he needs to know about composition of units that s/he is fighting and composition of flanking units and composition of rear units

If unit is infantry and it is to be reinforced,
then it will be reinforced with tanks

If unit is tanks and it is to be reinforced,
then it will be reinforced with infantry

If echelon is brigade and enemy conducts a company-size, limited objective attack,
then brigade personnel need to know what happened on the flanks of that company

If enemy is conducting an attack,
then size of the attacking force is proportional to the size of the objective

If a battalion uses only one company to attack,
then it may be a limited objective attack

If unit is tank battalion,
then it will not reinforce its companies with tanks

If enemy battalion is not tank,
then it may be motorized rifle

If goal is to reinforce subunits and unit is regiment,
then take tank company from tank battalion and give it to motorized rifle battalion

If goal is to reinforce subunits and unit is motorized rifle battalion and it has been given tank company by regimental commander,
then break up tank company and give platoons to motorized rifle companies

If enemy on defense,
then 2/3 artillery range will be inside own lines

If attack has limited objectives,
then will be preceded by artillery barrage of 10 to 15 minutes

If attack is major,
then has artillery barrage of 30 to 60 minutes

If force is attacking,
then it needs force advantage of 3:1 to 6:1
and it is weighted with tanks
and it is supported by artillery

If force is meeting engagement,
then needs 3:1 for a ratio to win

If enemy forces are spread out,
then there is not enough strength to defend along frontage, or
there is not enough time to display, or
the enemy does not expect effort and that avenue of approach

If enemy bringing up material to dig and having trouble resupplying at least one front,
then counterattack likely

If Soviets in defense,
then friendly attack was more successful than their attack

If Soviets in deliberate defense,
then look for counterattack force within the next 24 to 36 hours

If battalion CP is collocated with regimental CP,
then the unit is not combat effective and is consolidating CPs,
or the 2d echelon has moved up,
or the exploitation force or counterattack force is being held back

If the enemy has three segments on line,
then the enemy is not expecting a friendly attack in strength,
or enemy attack was a supporting attack since the forces were not concentrated

If it is a tank division,
then the tank force is used for reconnaissance

If unit is a motorized rifle regiment,
then tanks are used for exploitation force

If overhead cover is used and if the nuclear capable units are moving forward,
then the enemy may be ready to use nuclear weapons

If a Soviet column of tanks is moving forward,
then a reinforcing force may be present

If a defense is established without security zones and defensive belts,
then the defense is short term in preparation for a counterattack

If defense is hasty,
then mines may be emplaced by hand

If defense is deliberate,
then mines may be emplaced mechanically

If the objective is terrain,
then the attack may be more spread out

If tanks are dug in,
then the threat is defending

If troops are in an assembly area,
then something may be about to happen

If the forces are concentrated in an area,
then it is likely to be a main attack

If the enemy restricts fire of its artillery unit,
then the enemy is trying to avoid being detected or the enemy wants to save them

If a company is straight infantry or straight motorized,
then enemy action is less important

If ribbon bridge is emplaced by enemy,
then enemy is preparing to attack

b. Organization/Equipment

If report is about companies,
then infer that unit getting report is brigade level and sender of report is battalion S-2

If person is battalion S-2,
then s/he will get reports on squads and platoons

If fighting in Germany,
then opponent is Warsaw Pact, probably Soviet

If echelon is division,
then staff are concerned with battalions

If unit is Scale Board Battalion,
then target is corps and above

If two tank regiments are moving in parallel at the same time,
then they are likely to be a single tank division

If enemy on defense,
then they will use wire more than radio

If enemy is on defense,
then 1/3 of SCUD range should be in front of enemy front lines

If the unit is reinforced with A,
then the unit is not of type A

If adjacent units are both type A,
then a higher level unit is type A

If adjacent units are different types,
then the higher level unit can be either

If the number of enemy tanks equal 12,
then it is likely to be a tank company

If there are antitank guided missiles,
then the enemy is an infantry force

If enemy vehicles are wheeled armored vehicles,
then the unit is a motorized rifle unit

If SA2, SA4, and SA6 system radars are present,
then an enemy army is involved

If SA2 radars are present,
then enemy level is Front

If SA4 radars are present,
then enemy level is Front or Army

If SA6 radars are present,
then Enemy level is division

c. Other

If grid coordinates are given for a unit,
then assume they are the center of mass for that unit and that the unit may be dispersed around that center

If coordinates are given for a company,
then the company might be spread out around a 500 meter radius from the coordinates reported

If goal is to determine dispersion of an enemy unit,
then look at flanking units

If battle lasts 4 to 5 days,
then not many people will be left to operate tanks for deliberate defense

If enemy digging in and using refugees to dig and their attacks have limited objective,
then their strength is significantly low

If heavily guarded installations are near the FROG unit and if they are displayed forward,
then a nuclear attack may follow

If a unit has main attack responsibility,
then usually this unit gets first priority in supplies

If there are two salients (one into their territory and one into ours) and they did not attack,
then we attacked

If there is radio silence,
then perhaps enemy on defense

If engineer units and building materials are moving forward,
then deliberate defense is likely

If unit is antitank battalion,
then it needs trenches and bunkers

If an area is getting higher priority of emergency and building materials,
then greatest threat/risk is in that area

If unit constructs boundary,
then they should be recognizable pieces of terrain

If terrain is heavily treed,
then the terrain is not good for tanks to maneuver

If the objective is a city,
then the attack is more canalized

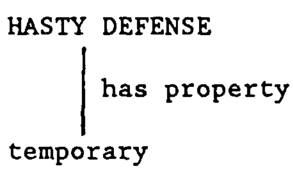
If the tanks are clean,
then it is probably a fresh unit (passage of lines)
If there are good natural boundaries,
then it is likely to be a unit boundary

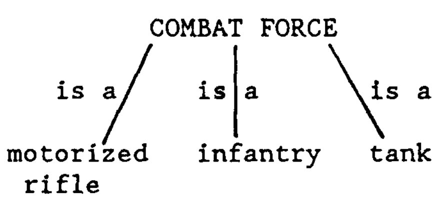
If the terrain is broken up,
then enemy movement will be slow

If civilians are doing military tasks,
then the soldiers are doing something else or the enemy strength is low and speed is essential in putting in defensive positions

If engineer units and building materials are moving forward,
then supply routes have increased

2. Semantic Networks





ENEMY UNIT

type — tank

type — motorized rifle

type — battalion

level — company

level — division

DIVISION

has-part

regiment

has-part

battalion

has-part

company

TANK FORCE

has-part

antitank guided missiles (quantity: 0)

DELIBERATE DEFENSE

has-part — commo trenches

has-part — overhead coverage

has-part — mines

has-part — anti-tank guns

has-property — dug-in

has-mission — hold ground

has-part — hull down position

has-part — security zone

has-part — defensive belts

HASTY DEFENSE

has-part

prepared overhead cover (quantity: 0)

mines

commo trenches (quantity: 0)

motorized rifle division
part-of

ANTITANK BATTALION

has-part
100-mm tank
guns (qty: 12)

has-part
batteries
(qty:2)

ARMY

DIVISION

has-part — SA2 is-a radar — has-part

has-part — SA4 is-a radar — has-part

has-part — SA6 is-a radar — has-part

MOTORIZED RIFLE COMPANY

has-part units
(quantity: 4)

has-configuration
2 units up
2 units back

TANK BATTALION

has-part
tanks
(qty:30-31)

has-mission
reinforcing
force

has-mission
counterattack
force

has-mission
attack force
(mode neg)-
means not this
mission

COMBAT

has-mission
neutralize
enemy's ability
to complete

has-mission
kill enemy
(mode-neg)

ANTITANK WEAPON
is-a
Sagger BRDM — part-of
motorized rifle unit

II. ORDER OF BATTLE KNOWLEDGE BASE CONSTRUCTS

A. Order of Battle: Interpretative elicitation methods

1. Scripts

Script: Order of Battle

Tracks:
1) Defense with loss of assets
2) Weather (cold and heat)
3) NBC environment
4) New information with no order of battle action
   a) get more sources of information to confirm
5) No information

Actions:
a) Use doctrine
b) Use local populace (embassy defense attache)
c) Use interrogators
d) intercept transmissions

Goals: Inform commander whom he is facing, what threat is made up of, tactics, capabilities, how Soviet commander is going to fight.
Suggest weaknesses and ways to beat enemy (e.g., psychological operations to get masses on friendly side, use of firepower).
Advise commander on how to employ his systems so as to get Soviets to respond in way advantageous to friendly.

Personal Goals of OB Tech:
1) Be first to know about critical information and conclusions
2) Be able to piece parts of puzzle together

General Plan: Integrate pieces of intel that are reported to produce coherent, doctrinally consistent picture. Request collection of information of critical and uncertain facts.

Entry Conditions: Bring to battle: good working knowledge of Soviet doctrine, tactics, training, equipment, commander personalities, basic weaknesses and vulnerabilities, knowledge of U.S. systems, tactics friendly commander's style and information requirements

In Battle: OB done ongoing
New information triggers process

Props: Humint, sigint, photo info, technical info, OB handbook, communication links, telephones FM radios, overlays templates (situation, event, decision support, terrain), maps, microfix, RATT rig, SB-22 switchboard

Roles: ASPS staff (OB tech, NCO in charge, chief of ASPS)
TCAE (technical control and analysis element)
CEWI BN
G-1 NCOIC
G-2 NCOIC
G-3 NCOIC
G-4 NCOIC
G-5 NCOIC
Fire support element of division artillery (has function: targeting)
Air Force weather personnel
Terrain detachment
Chemical and biological radiological element
Cavalry unit

Results: Situation report; intelligence report; four paragraphs in FEBA, enemy disposition, activities and expected enemy courses of action; situation map on overlay

Scenes:

1) When come on shift hear briefing presented by outgoing shift leader

   Actions: Focus on major units and expected enemy courses of action

2) Study map and situation

   Actions: Look at composition and disposition of enemy forces
   See how close to FEBA
   See if barriers constructed
   Look for artillery units (RAGs, DAGs)
   i) Look at relation to FEBA--if close then offense indicator
   See what is near objective

3) Conduct terrain analysis

   Actions: Look for highways into area where own unit will be operating
   i) See where enemy can come from

4) Use order of battle to fill in missing data

   Actions: Look at symbols for units on maps
   i) If none are there, then get information from OB about units not posted guess where units might be based on doctrine, type of

unit, and terrain (e.g., BMP better off-road than BTR)

5) Identify gaps in information and prioritize

Actions: See what information you do not have (look for gaps)

If some force-element components present (sufficient to imply a particular size of unit but not all),
then look for element missing (e.g., if identify three rifle regiments, where is 4th? where is artillery CP?

In general, the absolute size of piece or value of piece if missing information is not the most crucial goal for prioritizing collection. Value relative to success of friendly commander's goal is primary.

If collecting information for targeting, the relative importance of an object would matter, e.g., main enemy CP a good target.

Independent of commander's goals, other characteristics that prioritize collection:

1) Nuclear and chemical operations units, deployments
2) Artillery positions-has property-can suppress friendly antitank weapon

Generate hypothesis about what information might be missing (i.e., what "truth" is).
Generate assessment of information needed to test hypotheses.
Prioritize information by how critical it is to determining how enemy can impact on commander's plan.
Look at information requests that have been fulfilled and those still requiring tasking.

6) Develop event templates

7) Develop named areas of interest (NAI)

Actions: Take information requirements and look at roads enemy can use, especially crossroads where enemy can change direction.

Look for moving targets
Look at bridges for enemy crossing
Look at avenues of approach

8) Request information from collection manager

Actions: Prioritizing collection of enemy location according to what enemy forces are close enough to pose immediate threat to enemy forces.
Look at enemy 2nd echelon coming to reinforce (maneuver elements, lead elements, artillery, radars (location ID)).
See if FROGs prepare to attack
See if enemy prepared defensive positions.
See if tank units attacking or moving forward.
See if enemy clearing obstacles; indicates attack ID of divisions facing

9) Process incoming information and screen same

Actions: When report comes in see if relevant to targeting - pointer to Fire Support subscript
a) If SCUD then go to FSE, also tell G-3 and G-2

Assign log number

Glance through to see if immediate value to fighting
a) If regiment is moving, notify officer in charge of ASPS.

Determine whether to post on map or other filing system.

a) Criteria for not posting/ rejecting report info.:

- o High volume/low information value data causes clutter, confuses SITN map unnecessarily

- o No special interest in reported activity

- o Force level reported [more than two levels down or one level up] and [activity reported was expected]

b) Process reports for range of force levels of concern to OB analyst on two levels down and one level up

c) Other information to post to files

- o In addition to info reporting uncertain or unexpected enemy activity post new info concerning:

  1. biographical/personal factors, enemy commanders

  2. enemy vehicle characteristics
  3. enemy weapon system characteristics

  This information goes to common posting area (reference files)

d) Posting to Situation Map: Assessment of implications of data for the picture on the map done before posting made. Does new data make map more informative, e.g., change the picture/than without it? If not, do not post it. Look for data previously missing

Write notes on report, e.g., whether report is useful, where to post, etc. If reports do not make sense then re-check with source.

10) Prioritize Information to Analyze

Actions: Prioritize by what can kill friendly forces or leave them in a vulnerable position (e.g., split forces) or what assets of enemy (composition and disposition) can keep unit from performing mission

a) consider nuclear capable forces first
b) consider chemical warfare second
c) airborne forces
d) artillery systems
e) missile systems
f) maneuver forces

11) Analyze Information

Actions: If report comes in which contradicts expectations of enemy doctrine, then report may be inaccurate (source wrong or deceived) or report man be wrong resolution and collect information to resolve conflict.

Do predictive and situational analysis in cycles.

Use situational analysis to verify and validate predictions of predictive analysis.
Don't take Soviet doctrine as immutable, they may change way they do things if doctrine doesn't work.

12) Write INTREP every six hours

13) Make sure reports are disseminated through commands to Corps BDE, BNs, Companies, DISCOM

14) Deliver briefing

Actions: If don't know something, be honest about it.
Report uncertainty to commander but give worst case that commander should prepare for.

15) Update information requirements and new taskings for commands
   a) Develop new NAI's

<u>Subscript:</u> <u>"Hypothesis Formation"</u>

Hypothesis formation is part of the process of updating the current OB. The OB analyst forms hypothesis about enemy CA and from these generates information requirements to refute/confirm hypothesis. See Main OB Process.

Entry Conditions: Have current enemy OB and situation map with current available reports posted

Have generic knowledge, or access to basic information about how an enemy would attack

Props: Situation Map
INTEL Reports
OB Handbooks reference in enemy composition, behavior

ACT 1: Look at how much emphasis the enemy is placing in a given sector of the battlefield; i.e., the troop strength, and massing of forces, as well as composition of forces.

If force strength at location x appears to be increasing, then location x may be the location of main attack.

ACT 2: Look for potential objectives (this is a refinement of analysis of ACT 1) in hypothesized area of attack.

2.1 Use knowledge of terrain to determine potential objectives

2.1.1 Do terrain analysis; i.e., identify "key terrain," choke points, decision points.

Since current reports are obsolete, mentally project where they (the enemy) is going, and discard information that had only immediate benefit (and would now be obsolete).

Subscript: OB for Fire Support

Entry Conditions: OB analyst has a basic understanding of priority of targets; generic to objectives. It is up to fire support to decide whether to commit asset.

Props for OB for fire support/targeting:

HUMINT	has property	ususally not timely enough to be used		
SIGINT	has property	usefulness for targeting diminishes in minutes	causes	artillery
		implies		has-property
		How long was artillery there before it got reported?		moves every 1-1/2 hours

Actions: Whenever a report comes in, do a cursory examination of it to determine whether it has value for targeting. Timeliness of intelligence is critical to accurate targeting fire support. If valuable for targeting, call fire support and pass along the information.

Script: Soviet Attack and Defense

Tracks:
1) Type of battle
   a) offense
   b) defense

2) Type of terrain
   a) open
   b) wooded
   c) hills and mountains
   d) marsh
   e) snow
   f) rivers
   g) soft sand desert

3) Type of unit
   a) motorized rifle
   b) tanks
   c) artillery

Track: Offense

Scenes/
Actions:
1) Artillery prepares attack to keep enemy down, closed up and on defense
   a) shoot at command post, personnel and logistics
   b) if attacked by artillery, move and look for best terrain, or
   c) try to knock out artillery or elements that control artillery, or
   d) shoot own artillery at enemy artillery, or
   e) destroy preplanned obstacles along avenues of approach

2) Tanks move forward to exploit through direct fire
   a) tanks shoot at other tanks

3) Motorized rifle cleans up after tanks
   a) fights smaller resistance

Track: Motorized Rifle/Offense

Scenes/
Actions:
1) Battalion task force leads attack with tanks
2) Infantry fighters
   a) normally fight dismounted

b) if enemy strong or in NBC environment or light defense then fight mounted

3) Radio silence
4) Jamming friendlies

Track: Tank/Offense

Scenes/
Actions: Tanks lead as exploitation force

Track: Artillery/Offense

Scenes/
Actions: Enemy assigns division artillery to regiment artillery is placed forward and used to augment firepower fire for 50-60 minutes before division size attack

Tracks: Offense/Open Terrain

1) No effect on battle

Offense/Wooded Terrain:

1) Enemy goes in long columns or across wider frontage as approaches attack
2) Tanks harder to attack so use dismounted motorized rifle troops
3) Motorized rifle may precede tanks
4) Artillery less effective

Offense/Hills and Mountains:

1) Slows things down

Offense/Rivers:

1) Require engineer assets - pontoon boats or bridges

Offense/Marsh:

1) Bypass marsh

Offense/Snow:

1) Slows things down

Offense/Soft Sand Desert:

1) Slows things down
2) heat could cause fatigue in troops
3) heat could cause equipment to breakdown faster
4) lack of water

Track: **Defense**

Scenes/
Actions:
1) Enemy organizes companies and platoons and strong points
2) Enemy sets up minefields, obstacles, and barriers
3) Enemy tries to entrap friendly forces in kill zones and fire zones
   a) artillery exploits fire zones
4) Tanks counterattack

Track: Motorized Rifle/Defense

Scenes/
Actions: Organize around strong points of platoon or company size
Tanks placed behind motorized strong points to break through and allow motorized rifle to continue fighting.

Track: Tank/Defense

Scenes/
Actions: Tanks are to rear of strong points as a breakthrough force

Track: Artillery/Defense

Scenes/
Actions: Artillery is placed back

Tracks: Defense/Open Terrain:
1) Enemy digs in more

Defense/Wooded Terrain:
1) Units spread out more, maybe in squads
2) Troops hide in trees
3) Harder for overlapping field of fire

Defense/Hills and Mountains:
1) Ideal because can use reverse slope, pointer to M-M Reverse Slope
2) Friendly place on other side of hill
3) Artillery shot at higher angle and move forward

Defense/Rivers:
1) Defense with river in front
2) Shoot enemy as they cross river

Defense/Marsh:
1) Not defend marsh unless it is around a city
2) Defense area near marsh to force enemy into marsh

Defense/Snow:
1) Coldness may affect troops and equipment
2) Slows things down

2. Frames

Frame: Order of Battle

Function: Order-of-battle analysis

Echelon: Division

Part-of: G2 inteligence function

Has-Staff: OB Technician
- has number: 1
- is-type: warrant officer
- has-property: 100% time dedicated to production of OB

OB/Analyst
- has number: 1
- is-type: NCO
- has-property: 25-50% time dedicated to production of OB

Has-Acronym: OB

Has-Input: Knowledge of enemy force doctrine
enemy tactics
enemy training methods
enemy equipment

Frame: knowledge of equipment

has-part: knowledge of vehicles
has-property:mobility

has-part: knowledge of weapon systems
has-part: weapon use
has-part: fire range
has-part: fire angle
has-part: obliquity

knowledge of enemy compensabilities
enemy force strength
EW, communciations (radio)
enemy force composition
enemy force disposition

Frame: Head OB Analyst

Has-prop: much predictive analysis done before conflict begins

Has-prop: read all new info on enemy forces

Has-prop: connects current info to past instance, draws relationships, analogies

Has-prop: knows where to find info needed
Has-training: combat arms

Has-knowledge: enemy facing, Soviet OB, area going to fight, unit mission, collection assets, other staff members, type of unit fighting, enemy unit history

Frame: OB Products

Case: In-garrison

has-part: black books
has-part: cable book
has-part: intel bulletins
has-part: special reports

Frame: OB Products

Case: In-combat

has-part: INTSUMs
has-part: PERINTREPs
has-part: spot reports
has-part: OB overlay
has-part: situation map
has-part: intel journal

Frame: OB Analysis

Has-part: situational analysis
    has-part: intel on enemy past action
    has-part: enemy doctrine
    has-part: enemy personalities
    has-goal: assess enemy intent
        assess what enemy is doing
    has-role: support commander's decision making
        validate predictive analysis
    is-a: continuous cycle, alternating with predictive analysis

Has-part: predictive analysis
    has-part: enemy weaknesses
        has-part: C^2 vulnerabilities
    is-a: continuous cycle: alternating with situational analysis
    has-part: intel on enemy action
    has-role: support commander's decision making
        guide intel collection request
    has-goal: identify opportunities to exploit enemy weaknesses
    has-goal: predict what enemy will do

Frame: Enemy Force Strength

Format: Force strength tables in OB files and OB cards

IF you receive intel report of enemy forces destroyed
THEN you record it in your OB file &/or OB cards

Source: Enemy doctrine
Records of cummuluative enemy losses

Frame: Enemy Disposition

Is-a: Enemy location

Has-part: Last location, current location, predicted location

Frames of Components of OB Analysis Frame

Frame: Enemy (Soviet) doctrine

Is-a: Description of the set way an army will employ its personnel and equipment

Used-for: Training forces for operation under wartime conditions

Has-prop: Probably will be modified based on actual wartime experiences

Has-Source: Soviet newspapers, Soviet military publications, monitoring Soviet exercises

Frame: Enemy Tactics

Similar-to: Enemy doctrine

Is-a: Internal mechanism enemy really follows to achieve goals prescribed by doctrine

Frame: Enemy Training

Similar-to: Enemy fighting

Has-prop: Rigidity

Used-for: Assessment of combat effectiveness, enemy force vulnerabilities

Frame: Soviet Force: Weaknesses/Potential Vvulnerabilities

Part-of: Intelligence info on Soviets

Has-vulnerability: Requires extensive use of traffic controllers

Has-source: Troops below senior level officers are not trained to read maps

Has-implications: Disrupt troop movement by interdicting traffic control communication with higher HQ, and communication between traffic controllers

Mental Model	Mental Model
interdiction	C^3 process

Frame: Soviet Order of Battle

Frame-of: Fighting force

Has-part: Composition, tactics, doctrine

Frame: Soviet Defensive Formation

Has-parts: Tanks, divisions, artillery, radars, second belt, security zone, engineers, building supplies, motorized rifle units, division CP

Description: Lack of activity

Spatial Configuration:
Tanks back
artillery back - 2/3 range to FEBA
second belt division command post 15 km from FEBA
radars back
wide frontage
motorized rifle units up
security zone forward
engineer and building supply forward

Compared-to:
Hasty defense
has-part: security zone (mode neg.)

Frame: Soviet Offensive Formation

Has-parts: Artillery, radars, supplies, ammunition, food, POL, logistics, second echelon

Spatial Configuration:
Artillery up - 1/3 range to FEBA
logistics 15-25 km from FEBA
second echelon up - less than 15 km from FEBA
radars up
narrow frontage

Frame: Regimental Artillery Group (RAG)

Has-parts: Battalions (quantity: 3)

Part-of: Regiment

Spatial Configuration: Regimental cp in center
2BN up, 1BN back
in center of radar

Frame: BTR

Frame-of: fighting machinery

Is-a: armored vehicle

A-kind-of: tank

Similar-to: BMP

Has-part: armor
has-prop: thin skinned

Part-of: infantry

Compared-to: BMP
armor thinner in BMP
less mobile than BMP, operates off roads worse
more easily destroyed than BMP

Frame: Soviet Forces

```
Has-part:   Combined Arms Army
            has-part:   motorized rifle division (quantity:3)
                        has-part: artillery regiment
                        has-part: anti-aircraft regiment (quantity: 1)
                        has-part: tank regiment (quantity: 1)
                        has-part: MRR (quantity: 3)
                                  has-part: Howitzer BN
                                            has-part: BMPs
                                  has-part: motorized rifle
                                            battalions (quantity: 3)
                                            has-part: BMPs
            has-part:   tank division (quanity: 1)
                        has-part: motorized rifle regiment
                        has-part: tank regiment (quantity: 3)
```

Frame: Chemical Forces

Has-part: Persistent chemical agent, non-persistent agents

Has-part: Spetznaz forces, air aerosol airborne agents

Has-prop: Train with chemicals

Spatial
Configuration: Forward and at flanks of main force

Frame: Technical Information

Has-part: Enemy equipment info
has-source: EAC intel

Has-part: Enemy weapon system info
has-source: EAC

Frame: OB Handbook

Has-part: Info general on enemy army organization
instance: MRR
has-part: MRBs

Has-part: Specific unit info; about personnel in specific armies and divisions
instance: commander MRD x is y

Has-part: Biographic info
has-characteristic: collected at EAC
has-characteristic: division commander can't collect it per se
has-characteristic: division may get from POW

Frame: HUMINT

Is-a: intel reports from any source

Has-part: PW report
has-part: enemy biographies
source: Brigade
echelon: Division

Has-part: IRR agent debriefs
preprocessed: No/None
reliability: low
transmission rate: generally low/variable
source/accountability: little/none
special handling
instructions: calibrate individual agent's reliability accuracy if possible
IF want to calibrate agent,
THEN you need to get more than one report from that agent

Frame: SIGINT

Is-a: Intel report

Has-part: ELINT
is-a: report
has-a: electronic signal identification
instance-of: radar type

Has-part: Enemy radar deployment rule
part-of: enemy doctrine
has-charac: usually accurate
has-charac: don't accept as gospel
has-charac: accidental or purposeful deception
instance-of: march in formation produces simultaneous & mixed emission of different signals
instance-of: wrong identity or interpretation of signal data

Has-part: Most radars are for a single purpose
part-of: radar's characteristics reflect its mission
e.g.: gun dish radar different from land radar

Frame: PHOTINT

Is-a: Intel report

Has-type: Photos
source: AF reconnaisance
has-charac: not typical

Has-type: SLAR
is-a: side-looking airborne radar
is-a: given number of "still shots" in a defined interval of space

Has-type: Moving target indicator
a-kind-of: radar info
is-a: vehicle(s)/object(s) moving @ > 5mph
has-charac: high data volume
has-charac: info value/unit data is low
has-charac: low resolution; can't distinguish hostile vehicles from neutral/friendly vehicles
handling instructions: in general, MTI info not worth recording

3. Mental Models

Mental Model: Reverse Slope

Context: Battle fought on hills

Goal: Friendly force wants to destroy enemy force

Objects: Hills, enemy force, friendly force

Forces: Friendly and enemy combat power

Force/Object
Interactions: friendly force hide behind hill
outcome: enemy can't see them
enemy comes to top of hill
outcome: enemy in friendly line of size
friendly attack enemy force

Outcome: enemy force destroyed

Mental Model: Why Soviets Keep Chemical Agents on Their Flanks

Context: Battlefield

Goal: Protect own forces from destruction (destroy friendly forces)

Object: Terrain, persistent chemical agent, friendly forces, Soviet forces

Forces: Friendly and enemy combat power, lethality of chemical agents

Force/Object
Interactions: Maneuver forces advance
If chemical agents in front and units get exposed, then will die
To avoid, enemy keeps chemicals on flank away from units

Outcome: Enemy units not exposed to chemicals

Mental Model: Force C^3 process

Context: Battlefield

Objects:

1) Commander of forces HQ (goal: initiate communication of commands for action and operations; terminal point for communication of current status of operations from troops)

2) Communication nodes (goal: receive command messages from previous node(s), subsequently transmit messages to other nodes)

3) Communication links (goal: carry message from transmitter node to receptor node)

4) Troops/command (forces) (goal: execute commands received from HQ)

Forces: Electronic, optical, auditory transmission/reception of information for command and control

Force/Object Interactions:
Command: HQ link to node to link to troops
Control: troops to link to node to link to HQ

Outcome: If all components function properly, then command and control effective, else C^2 ineffective and confusion results

Mental Model: Friendly Interdiction of Enemy

Context: Battlefield

Goals: Friendly force wants to destroy or significantly reduce enemy force capability to carry our planned operation. Enemy force wants to carry out intended processes and operations.

Object: Friendly force
Enemy force

Forces: Friendly combat power
Enemy combat power

Force/Object Interactions:
IF friendly force successful,
THEN friendly goal achieved, enemy goal prevented.

IF friendly force not successful,
THEN enemy goal achieved, friendly goal not achieved.

B. Order of Battle: Generative Elicitation Methods

1. Production Rules:

a. Tactics/Doctrine

If terrain is wooded,
then use motorized rifle units for cover and concealment

If unit is tanks,
then use an open terrain

If enemy is going into prepared defense,
then he will set up defense belt and security zones and barricades and will probably not see counterattack

If enemy has a security zone,
then it is more difficult to attack

If enemy is not using security zone on defense,
then he may not have enough troops or they are changing their doctrine in the way they attack

If enemy is using security zone on defense,
then main defense belt moves forward

If enemy not using security zone on defense,
then use IPB template to see what kind of offensive or defensive situation enemy will use

If unit is going into a hasty defense,
then he will set up no security zone and he will set up local security and 2d echelon will not be ready to be committed and he will counterattack

If enemy 2d echelon is ready to be committed,
then enemy will not go into hasty defense

If enemy is committing additional forces,
then place being committed is enemy's main effort

If enemy is going from hasty to permanent defense,
then will leave security forces in contact,
then withdraw main forces,
then withdraw security forces

If Soviets having lack of success and 2d echelon is having problems,
then Soviets may introduce chemical and nuclear weapons to regain initiative and momentum

If there are no indicators of chemical or nuclear attack and enemy not having success and second echelon having trouble being committed,
then continue to look for indicators of chemical or nuclear attack and brief that there is no evidence

If main effort is having lack of success,
then expect follow-on forces to be shipped

If follow-on forces get shipped somewhere else,
then main effort changes

If enemy having success in an area,
then will ship forces to that area

If unit goes or radio listening silence,
then it is probably getting ready to attack

If	Soviets are going to attack joing with 2 units,
then	they typically will be 2 tank units or 2 motorized rifle units
If	unit is in rear and getting priority of assets,
then	it will join battle first
If	a unit goes on radio listening silence,
then	it may attack and friendlies can't pick them up on radio anymore
If	enemy attacking in one area and defending in another,
then	he is probably shifting his effort
If	enemy restricts its artillery fire,
then	he is probably running low and won't be resupplied for a while
or	may not have target locations
or	front line/major forces can defeat friendly without counterbattery
If	front is having lack of success and is running low on ammunition,
then	it will go on defensive
If	enemy is not having success,
then	it is a good time to counterattack
If	enemy is going to attack,
then	may send reconaissance element forward
or	jam friendly communications
or	use smoke
or	have river-crossing elements forward
If	enemy is attacking,
then	they will bring bridging assets foward
If	enemey is reinforcing,
then	look for counterattack
If	unit on defense,
then	they will bring engineers forward to build barricades in front of its position and to dig defensive tank ditches and set up mine fields
If	engineers have building materials,
then	they are probably going to build barricades
If	enemy is attacking,
then	he will fire field artillery first

If friendlies can't monitor enemy transmissions,
then enemy may be on radio listening silence
or range of equipment might not be great enough
or terrain may block transmissions
or may be encrypted

If entity is a potential target and unit has weapons to attack it,
then entity is of interest to unit as target

If entity is within area of operations or area of interest of unit,
then it is of interest to unit

If Soviets are at war,
then the objectives are to advance 30-50 km/day

If unit defends fixed site,
then it is unlikely to move short distances

If SCUD unit communicated several hours ago and no attack has been launched yet,
then communication was probably not an attack order

If air defense is located by river,
then it is probably protecting river crossing site

If enemy is on defense,
then he will blow up bridges

If Soviets wish to destroy friendly aviation assets,
then they will strike ground assets with missiles
and use surface to air missiles to his airborne elements
and use air to air tactics

If range of unit is short,
then assembly area must be close to target

If signal security placed on unit,
then it may be getting ready to attack

If enemy is engaging in barrage jamming,
then it is an attack indicator

If enemy brings chemical defense forward,
then he probably will use it

If enemy is going to use chemical assets,
then he will bring artillery assets forward

If enemy airborne unit is in battlefield,
then enemy will not use nuclear weapons
If enemy conducts a limited objective attack and retreats,
then he is probing for friendly weaknesses

If enemy finds weaknesses in friendly force,
then he will lead attack through that weakness

If enemy conducts an attack with battalion,
then it is a more major attack

If locate forward units of bigger unit,
then infer attack will occur where forward units are going

If enemy force moving,
then direction of movement may indicate where attack may come

If enemy is defending,
then frontage is wider than if attacking

If enemy is defending,
then command posts and artillery are farther back from FEBA than an offense

If enemy is in transition from offense to defense,
then units may still be forward

If tanks are dug in,
then enemy is in defensive position

If enemy is going to attack,
then he will precede attack with artillery barrage

If enemy used short artillery barrage,
then it is probably for defense

If air assault unit is in staging area,
then it will be deployed shortly

If enemy has 5 divisions,
then they probably will place them 3 up (MR, T, MR) and 2 back

If friendly is attacking,
then need to assess percentage of losses that can occur from indirect fires

If goal is to reduce enemy strength prior to attack,
then use indirect fire

b. Organization/Equipment

If unit is designated "Guards",
then it is Russian

If enemy not Soviets,
then not have chemical and nuclear weapons

If goal is to assess likelihood of nuclear and chemical attack,
then need to know locations of surface-to-surface missiles, masking activities, and locations and activities of nuclear capable weapon systems or aircraft

If unit talks to higher unit,
then it is probably subordinate to that unit

If identify new unit,
then use order of battle to see who parent is

If army running low on counterbattery artillery,
then can't give any to subordinate divisions -- pointer to M-M supply-and-demand

If friendly unit is corps,
then it will face an army

If goal is to establish FEBA,
then find out where forward units are and draw line there

If U.S. fighting a battle,
then they will have an operations order
and know mission
and area
and have maps
and have mission statement
and have done preliminary intelligence analysis on area of operations and avenues and probable enemy will be facing
and will have collection plan
and have intelligence requirements of the commander

If road is an autobahn,
then it is good for tanks

If road is good for tanks,
then they probably will be placed there

If Soviets are not being successful,
then infer that they are using up their forces

If Soviets using up their forces,
then infer they will bring in their next echelon

If subunits dispersed according to how far one would expect to see in one larger unit,
then infer that they probably form that larger unit

If unit is tank,
then it will fight tanks with tanks

If unit is motorized rifle,
then it will fight tanks with anti-tank weapons

If information concerns radars,
then it does not differentiate types of division

If SCUD is communicating to army,
then assume it is subordinate to that army

If air defense radar is being moved,
then it will move more than 3 kms

If radar is detected,
then look within a 5 km radius to confirm location

If division has engineering assets,
then probably won't lend them to another division

If Scale board is detected,
then it is part of Soviet force only

If Soviets send out reconnaisance elements,
then main body of division will be 15-30 km behind regiment

If FROG moves forward,
then it may be ready to fire an offense

If goal is to guess how many divisions on defensive,
then divide frontage by doctrinal frontage per division

If unit is air assault,
then troops brought in by helicopter

If unit is airborne,
then troops parachute to destination from airplane

If enemy is on defense,
then he will suffer few casualties than offense

If artillery is over 120mm,
then it is nuclear capable

If Soviets are running a combined arms army,
then they will reinforce motorized rifle units with tanks

If enemy is on offense,
then he will have Operational Maneuver Group (OMG) on-line

If enemy is on defense,
then he will not have OMG

If enemy is preparing counterattack,
then he may have an OMG

If enemy is going to counterattack,
then he will use tanks

c. Other

If troops have guards honor,
then they may think they will get special priority

If unit gets first priority of supplies,
then they will probably head main attack

If one division has a better commander than another,
then it might get priority of supply from Army commander

If unit is required for mission,
then they will be given priority of supplies

If unit gets last priority of supplies,
then they are leading less important supporting attack
or they are 2d echelon
or they are in some kind of supporting role

If troops not given support when fighting
then morale may be low

If unit is going to attack,
then it will give first priority of supplies to main units and commit them to 1st echelon

If unit is going to attack,
then will give last priority of supply to supporting units and commit them to 2d echelon

If enemy is not getting supplies,
then it is weak

If enemy is weak,
then try to destroy him

If facing an enemy unit,
then ask collection manager for information regarding it

If enemy has no reinforcements and he is going on defensive,
then we are winning

If enemy is having difficulty in moving forces,
then friendly is winning

If need information,
then go to collection manager

If friendly forces hit Soviet logistics site,
then they will have trouble supplying great numbers of forces

If enemy has a lot of forces,
then supplying them will be a slow process

If enemy logistics are destroyed,
then enemy morale will be hurt

If on-line unit is not getting priority of supplies and another unit is getting ready to attack,
then second unit may be replacing front line unit

If front is having lack of success and is running low on ammunition and is attrited,
then they are no immediate threat

If more than average logistics communications are being recorded,
then enemy may be having resupply problems
or enemy is reinforcing

If unit is not getting supplies,
then may initiate logistics communications

If enemy communicates too often,
then they can be picked up by friendly communication

If friendlies intercept enemy communications,
then they can learn about their weaknesses

If not know whether units are tank or motorized rifle,
then look for assets belonging exclusively to one or the other

If find asset associated with only one kind of unit,
then infer it is that kind of unit

If SCUD is communications with higher unit,
then it may be requesting a target
or set up location
or getting ready to move

If terrain is mountainous,
then may block communications

If weather is rain or snow,
then may block communications

If entity is a potential target and unit does not have weapon to attack it,
then it is important for order of battle

If entity is important to mission,
then it is important to intelligence analysts and others

If Soviets have not advanced far,
then they are not meeting their objectives

If have identified two different command post locations,
then can draw unit boundary between them

If information is old and unit referenced is mobile,
then pull information off map

If information is old and unit references is fixed site,
then leave it on map

If entity is nuclear capable,
then put it on target list

If target is nuclear capable,
then it is high priority

If measuring equipment is not totally accurate and object being measured is not likely to change in small ways,
then assume small correction in measurement is due to original error in measurement

If higher commander is talking to lower commander and enemy is preparing to attack,
then lower commander may be leading the attack

If enemy is short of manpower or being cruel,
then may have refugees work for them

If friendly is attacking,
then need to hit enemy indirect fires

2. Mental Models

Mental Model: Effect of enemy nuclear weapons on enemy operations

Context: Battlefield

Goal: Destroy friendly forces

Objects: Friendly forces, enemy forces, nuclear weapons

Forces: Explosive power, residual contamination

Force/Object Interactions:
Nuclear weapons destroy friendly forces
area is contaminated
If enemy goes through, get killed
enemy must go around area

Outcomes:
Enemy movement hampered
Friendly forces destroyed

Mental Model: Using Motorized Rifle Unit in Surprise Attack

Context: Battlefield

Goal:	Attack friendly forces without detection
Objects:	Trees, enemy tanks, enemy foot soldiers, friendly forces, friendly sensing capabilities
Forces:	Noises, light (sight)
Force/Object Interactions:	Foot soldiers hide behind trees outcome: trees block sight of them from friendly Enemy uses fewer tanks outcome: creates less noise Sensing units not pick up enemy
Outcome:	Enemy attacks without detection

Mental Model: Influence of Terrain on Attack

Context:	Battlefield
Goal:	Enemy wants to take objective in friendly force area
Objects:	Enemy force, friendly force, terrain
Forces:	Enemy combat power, friendly combat power, movement capabilities of troops and vehicles
Force/Object Interactions:	Enemy has capability to move toward friendly forces terrain may have features which block movement capability Enemy redirects movement based on obstacles outcome: enemy is in different location Enemy in wrong place to attack friendly objectives
Outcome:	Enemy attacks new location

Mental Model: Economy of Communication on Battlefield

Context:	Battlefield
Goal:	Enemy units want to communicate to other enemy units Friendly units want to destroy enemy subgoal: locate enemy Enemy does not want to be destroyed subgoal: do not be detected by friendly
Objects:	Enemy units, enemy parent units, other enemy units, friendly units, friendly communication devices, enemy communication devices, friendly weapons

Forces:	Friendly combat power, electronic communciations signal
Force/Object Interactions:	Enemy uses electronic signal to communicate with other enemy units outcome: enemy units communicate Friendly communication devices get triggered, too. outcome: friendly knows where enemy is Enemy communcates as little as possible to avoid detection - only important communications with parent unit

Mental Model:	Economy of Force
Context:	Battlefield
Goals:	Attack one area, defend other area
Objects:	Friendly units, enemy units
Forces:	Friendly combat power, enemy combat power
Force/Object Interactions:	Enemy has two goals Enemy values attack more, hence wants to divert as many resources to attack as possible Enemy takes resources from defense and gives to attack
Outcomes:	Defense holds Attack succeeds